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Final Report

LEM Utilization Study for Apollo Extension System Missions

to

National Aeronautics and Space Administration
Manned Spacecraft Center
Advanced Spacecraft Technology Division
Houston, Texas 77058

by

Grumman Aircraft Engineering Corporation
Bethpage, New York

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Vol. VI Schedule Analysis

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Contract No. NAS 9-3681
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PREFACE

This report presents the results of the LEM Utilization Study (Contract NAS 9-3681) conducted by the Grumman Aircraft Engineering Corporation for the National Aeronautics and Space Administration, Manned Spacecraft Center. The following six volumes comprise the total report:

- Volume I - Summary
- Volume II - LEM Lab
- Volume III - LEM Shelter
- Volume IV - LEM Taxi
- Volume V - LEM Truck
- Volume VI - Schedule Analysis
- Appendix to Volume VI - Cost Analysis

Volumes 2 through 5 are independent of each other. Data and analyses applicable to more than one mission are included in the appropriate volumes.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 GENERAL

This volume contains the schedule data generated in accordance with the requirements of the LEM Utilization Study Contract NAS-9-3681. The cost data are included in Appendix A to Volume VI. In addition, subsystem and system design and development data, a prelaunch checkout analysis, a preliminary manufacturing plan, and a preliminary support analysis have been included. The budgetary estimated cost and schedules presented herein are for planning purposes only.

Two configurations each of the Lab and Taxi, three configurations of the Shelter, and one configuration of the Truck were studied at the subsystem and system level, and are reported on herin. A general description of each configuration is presented in Section 3, detailed discussions of the configurations are contained in Volumes 2, 3, 4 and 5 of this report.

1.2 ASSUMPTIONS

Cost/schedule data are based on the following guidelines, assumptions and conditions.

- No interference with the Apollo Program
- AE 65-1 launch schedule for flight hardware scheduling except Truck
- First Truck mission in 1972
- Go ahead for hardware acquisition 7/66
- Availability of LEM test articles is based on the proposed LEM Program Schedule No. 37 of 6-4-65.
- Fabrication and assembly of additional test articles for the various programs are phased into the LEM Program where openings now exist.
- A thorough preliminary design and some development testing of radiators is performed prior to the AES Program. Costs of this D & D effort are not included.
- Requalification of LEM subsystem hardware used on the AES configurations (without modifications) is not required for the launch and ambient environment. Tests for life endurance are conducted.
- The cryogenic storage and feed system and the power generation section used on the CSM does not require subassembly requalification for integration into the LEM Lab.
- Three each Lab, Shelter, Taxi and Truck flights.
- Installation of experiment hardware and payloads occurs at Grumman.
- Development spares, DMSM (Development Support Material) for support of fabrication/testing of production articles until acceptance, are included in the amount of two (2) sets of unique articles.
- Operational spares for support of production articles after acceptance are included in the amount of three (3) sets of unique articles-one (1) each for E.T.R., Grumman, and Subcontractor.
- All major test facilities are available.

2 SUBSYSTEM DEVELOPMENT

2.1 INTRODUCTION

The utilization of the LEM and its subsystems for extended missions on the lunar surface, and in lunar and earth orbit requires additions, deletions and modifications to the LEM subsystems for the specific missions. The LEM subsystems retained intact require additional tests to demonstrate performance for the mission profiles. The present scope, intensity and duration of the LEM test programs are designed to verify performance for the lunar landing mission profile. In each of the AES missions studied, the dynamic environmental envelope and the type of environmental stresses are not significantly different from the LEM environmental design criteria. The primary difference is the mission duration. Active life and quiescent storage time contribute to the test duration requirements for the retained subsystem hardware.

The following paragraphs summarize the significant modifications and development factors that are imposed upon each subsystem as a function of the mission configuration. Where modifications are not incurred, the mission configuration is not discussed. Tables 2.1-1 through 2.1-8 provide a further description to highlight the differences, at the subsystem level, between the representative configurations used for this cost and schedule analysis.

2.2 STRUCTURE SUBSYSTEM

The L.O. Laboratory, the Shelter and the Taxi all need additional micrometeoroid shielding because of the greater probability of damage during the longer missions. In addition, the thermal-micrometeoroid shielding is modified to provide penetrations for experiment support and for the viewfinder in both Lab configurations. The ascent and descent engine base heat shields are modified where these propulsion subsystems are deleted in the Lab or Shelter. Other changes in secondary structure are the addition of structural supports for the ECS radiator and FCA's for Labs 1 and 2 and Shelters 2 and 3, the addition of supports for various experiment configurations, and the complete relocation of subsystems and RCS in the Truck (descent stage). All modifications to secondary structure are verified by system level static and dynamic tests.

Modifications to primary structure include the addition of a viewfinder port to the crew compartment of both Lab configurations and the design of a completely new low profile descent stage for Lab 2. Where primary structure is modified or redesigned, developmental static and dynamic tests are performed on structural elements or subassemblies. Static and dynamic verification tests are also performed at the system level on the complete vehicle.

2.3 N & G AND S & C SUBSYSTEMS

Development tests are required of components of the guidance and control system for the Truck and Shelter. The automatic tracker assembly (ATA) qualification* consists of determining the ability of the ATA to acquire and track specific stars or their simulated equivalents under various environmental ambient and dynamic conditions.

Modifications to the LEM Guidance Computer (LGC) program require verification tests consisting of the determination of command signal outputs for orbital parameter and attitude inputs, and complete mission profile exercises. Upon completion of development of all modified units of the G & N and S & C subsystems, flight control system integration testing is required.

The demonstration tests required for the G & N and S & C equipment on the Taxi, consist of operation verification after 14-days quiescent storage at the estimated environmental conditions expected during the lunar stay. Both night and day mission extremes are considered. Where data exist for equipment already developed it would be used in lieu of actual testing.

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*May be accomplished on the LEM program.

2.4 CREW PROVISIONS SUBSYSTEM

Crew provisions in the Lab and Shelter involve consideration of packaging equipment and consumables based on extended mission requirements, as well as providing adequate facilities for two men to perform useful work during these periods.

Qualification testing is therefore required to verify the adequacy of containers to withstand extended storage requirements as well as to authenticate the developed storage concepts.

Structural testing is necessary to qualify those additions which are not common to the LEM, including beds, seats and restraint devices, work tops, and display panel modifications.

In addition, the verification of the adequacy of the interior arrangement based on human engineering principles and practices must be considered. This testing should involve simulation of all work tasks to insure that system operation is not degraded by the chosen equipment arrangement.

2.5 ENVIRONMENTAL CONTROL SUBSYSTEM

The necessity for additional design and development in support of the Lab configurations is primarily limited to the thermal control section of the ECS. The cabin circulation fan and the coolant circulation pump require modification for both Lab configurations. Radiators are added to the coolant loop and the water management system is replaced with the system designed for the CSM. Requalification of the modified components and life extension tests of the components retained are required to demonstrate satisfactory performance. The integration of the system and final verification of thermal control capabilities must be completed in the system tests.

Redesign of the coolant distribution network is required for Shelters 2 and 3, because of the integration of radiator assemblies, fuel cell assemblies, and the deletion or addition of cold plates into the thermal control section of the LEM ECS. Development and qualification tests on both a component and subsystem level are required.

The addition of tankage to contain additional ECS water and oxygen for Shelter configuration 1 necessitates subsystem level testing to verify manifold designs and delivery equipment modifications.

Requirements for design, development and qualification of new ECS hardware are limited to the thermal control and water management section for both Taxi configurations. Heating elements and associated controls must be designed and integrated into descent stage water tank assemblies. Operating life extension testing is required primarily for dynamic ECS components (i.e., coolant pump assemblies, water sublimators, and temperature and flow control valves) where operating time has been increased over present requirements. In addition, a non-operating standby capability must be demonstrated for all life support subsystem components in the projected thermal vacuum environment during quiescent storage. The utilization of the waste heat and integration of the RTG into the Taxi are best demonstrated at the system level. The RTG unit can be simulated electrically and thermally.

Subsystem level operational tests to demonstrate the performance of the reconfigured thermal control loop are required for the Truck.

2.6 INSTRUMENTATION SUBSYSTEM

The modifications required for the Lab and Shelter are primarily the removal of sensors and signal conditioners associated with deleted subsystems, and replacement of the LEM tape recorder with the CSM data storage equipment. Integration of the CSM tape recorder into the subsystem and the demonstration of performance are accomplished at the subsystem level.

The mission programmer utilized on LEM development flights is incorporated in the Shelter to meet the unmanned landing requirements and provides a remote activation and checkout capability. System tests in an ESI test article are required to demonstrate satisfactory performance.

The Taxi configurations require rewiring of sensors and signal conditioners to allow programming of power to those required during the storage phase. Verification of this modification is accomplished on the system test article.

A mission programmer, similar to that required for the Shelter, is added to the Truck to accomplish the unmanned mission. Integration and tests of the programmer are performed at the system level.

Extended mission duration operational and storage period demonstrations are conducted on all appropriate subsystem hardware. The tests are conducted in the operational condition of the item and in the simulated environment.

2.7 ELECTRIC POWER SUBSYSTEM

Integration will be required for the fuel cell power generator section into the Lab configurations and Shelter configurations 2 and 3. The extended life fuel cells require qualification for the power profiles expected on each mission. For the Shelter, an automatic startup controller is required and must be tested with the FCA. Quiescent storage of 45 and 90 days for Shelters 2 and 3, respectively, under simulated lunar ambient conditions, must be verified for both the FCA, the startup controller, and reactant storage tanks.

The RTG's integrated in Shelter configurations 2 and 3 and Taxi configuration 5 will have an output voltage that is too low to charge the descent battery. Either the DC-to-DC converter that is part of the RTG must be redesigned or a second DC-to-DC converter is required to raise the RTG output voltage. A control and distribution system is required to control and regulate battery charge. System performance tests are required to demonstrate satisfactory operation under the critical electrical mission profile.

The distribution system for the Truck is simplified by the removal of a large amount of LEM equipment. System breadboard configuration performance tests are required with tests simulating the nominal and critical design mission.

2.8 PROPULSION SUBSYSTEM

The Shelter, Taxi, and Truck configurations have vent valves added to the descent propulsion system. These are squib valves similar to the helium initiating valve with the possible exception of the port size. The test requirements are the same as those outlined for the RCS vent valves.

Lab configuration 1 requires an improved supercritical helium storage tank for the extended mission duration. System integration tests to demonstrate storage capability and subsequent operation and performance are required.

Lab configuration 1 also requires component testing to demonstrate the capabilities of the components to withstand prolonged exposure to pressure, propellant and/or propellant vapors and space environment. All components must undergo extended testing which is commensurate with the extended mission duration. The quad check valves, vent couplings and relief valves in the pressurization subsystem, and the fill coupling in the propellant feed subsystem must be tested to determine the significance of seal leakage and cold flow of teflon seats. The descent engine flow control and isolation valves and valve actuators must undergo extended testing. The solenoid valve actuators must be tested under prolonged exposure to vacuum to evaluate the sublimation of potting compounds and coil wire insulation.

The ascent propulsion system is included on the Taxi configuration. The only expected test requirement is extended life to meet the requirements of the extended mission of the Taxi configurations. Component testing, commensurate with the Taxi mission duration, similar to that outlined for the Lab descent engine is required. Equivalent ascent system components must be tested.

2.9 REACTION CONTROL SUBSYSTEM

The Shelter and Truck configurations have vent valves added to the RCS. These are squib valves similar to the helium initiating valves with the possible exception of port size. Component testing is required to verify the integrity and material compatibility of the valves. System integration tests including demonstration of thermal control capability are required.

The Shelter and Truck configurations utilize a single set of helium and propellant tanks. System integration tests are required to demonstrate and verify the Truck subsystem as the propellant lines have been reconfigured. LEM tests demonstrating the capability of the RCS to operate with either the A or B propellant supply is applicable to the Shelter configuration.

The Taxi and Shelter configurations have insulation covers for the RCS clusters. Component tests are required to demonstrate the capability of the Taxi's insulation cover deployment and retraction mechanism. These tests will be applicable to the Shelter as the cover design is the same although the mechanism requirement is less stringent, because the covers for the Shelter are deployed but not retracted. A system test of either vehicle is required to demonstrate the capability of the insulation covers to provide the required thermal control.

Taxi configurations 2 and 5 require component tests to demonstrate the capabilities of the components to withstand prolonged exposure to pressure, propellant and/or propellant vapors, and space environment. All components must undergo extended testing which is commensurate with the extended mission duration. The thrust chamber valves, and the ascent interconnect, crossfeed and isolation valves must be tested to evaluate the significance of sublimation of potting compounds and coil wire insulation in prolonged exposure to vacuum and to evaluate the significance of valve seat cold flow resulting from propellant pressure.

2.10 COMMUNICATION SUBSYSTEM

Extended life capability in both the operating and storage modes must be verified for the Taxi and Shelter configurations. A command decoder is required for the Taxi, Shelter and possibly for the Truck for the unmanned status transfer command function. This item requires development and integration with the receivers, and reliability and system testing.

The development of a new wideband receiver is required for the Shelter assuming a video transfer requirement exists from the scientific payload (i.e. mobility aid) to the Shelter. It must be compatible electrically with the transmitter (part of the experiment) and with the Shelter signal processor and must be integrated physically into the Shelter. An automatic switching capability is required to provide for switching between the S-band omnidirectional and steerable antennas for the command and transmit functions, respectively, during the unmanned Taxi and Shelter checkout periods. A manual capability presently exists in the LEM which must be modified to automatic based on programmer commands (with fail safe on the omnidirectional position). Also, for wideband status data transfer inflight (after occultation), the unmanned Shelter and Truck require information from the N & G computer to position the steerable antenna for signal acquisition and lock-on. The interface wherein the data is made available and fed into the antenna servo system, with automatic means for disabling when lock-on occurs, must be analyzed and the equipment modified to perform this function. Simulation tests are required to evaluate the modification.

2.11 CONTROLS & DISPLAYS

Control and display arrangements for the Lab and Shelter require the removal of those LEM subsystem controls and displays which are not pertinent to mission requirements. A major consideration is the incorporation of required controls and displays with minimum modification to existing LEM console layouts. Based on this concept, the only modifications required for the Shelter are the realignment of the front control panels to a vertical position while maintaining the same console shape. Additionally, in the Lab, the right side consoles require modification to provide sufficient space for Lunar Survey Equipment controls and displays. Structural pickup points as they exist in the LEM are retained.

In development of the design and arrangement of the control and displays subsystem adequate emphasis should be placed on the employment of human engineering principles and practices to insure that the system can be operated adequately under all anticipated conditions. The test requirements must, therefore, reflect and verify the incorporation of the human factors' principles.

All controls and displays incorporated are to be qualified based on the extended requirements placed on them. As such, qualification testing of indicator lights, gauges, toggle switches, rotary switches, flag indicators etc., should be performed under all feasible conditions of usage and storage. Simulation of startup of displays and controls after shutdown periods consistent with mission timelines for the Shelter and Taxi is required in the qualification testing, as well as increased cycling of indicators and controls employed in the Lab. Testing of this type should be conducted on a programmed basis to simulate all possible variations of mission time lines based on contingency or emergency situation.

TABLE 2.1-1

LUNAR ORBIT LABORATORY

CONFIGURATION 1

Mission Profile

- Apollo mission to lunar orbit insertion
- Polar orbit insertion
- Approximately 28 day lunar polar orbit flight
- Descent propulsion for abort

Subsystem	Modifications	Test Requirements
Struct	• Add micrometeoroid protection • Add support struct. for exper and FCA subass'y • Add support structure for radiator • Add viewfinder port.	• Demonstrate adequacy of standoff • Demonstrate support structure integrity. • Demonstrate viewfinder port struct. integrity, leakage
S & C	• Delete except DECA	• Verify extended storage life and subseq. operation
N & G	• Delete	
Crew Prov.	• Add LiOH & food (GFE) • Add work stations	• Verify adequacy of extended storage and subseq. utilization of LiOH containers • Verify interior arrangement (human factors)
ECS	• Add O_2 storage • Provide additional cold plates • Modify cabin circulator assembly • Substitute CSM water management system. • Provide radiator	• Verify extended operating life • Des., dev and qual. radiator • Demonstrate integration add'l cold plates and radiators in heat transport loop • Integrate CSM water management system into subsystem
Ldg. Gr.	• Delete	

TABLE 2.1-1 (cont)

Subsystem	Modifications	Test Requirements
Instr.	• Delete sensors and SCU not required • Integrate experiment data output with PCMTE (replace tape recorder with modified Gemini recorder)	• Verify extended operating life remaining subassy's • Demonstrate data management integration
EPS	• Replace batteries with CSM FCA's and cryogenics (Apollo X) • Add CSM inverters	• Verify extended operating life of distribution system • Integrate generation sys. with distribution sys.
Propul.	• Delete Ascent subassy's • Modify supercritical helium tank (vented, vapor shield tank) • Modify propellant tank supports	• Verify extended storage capability descent propellants and subsequent operation. • Dev. & qual. of new tank design
RCS	• Delete	
Comm.	• Delete system except for CM/LEM intercomm	• Verify extended operating life of intercomm
Controls & Displays	• Delete controls and displays of subsystems removed • Provide display panel for exper.	• Verify extended operating life of remaining gauges and switches • Qualify panel for experiments • Verify arrangement of C & D (human factors)

TABLE 2.1-2

LUNAR ORBIT LABORATORY
CONFIGURATION 2

Mission Profile

- Apollo mission to lunar orbit insertion
- Polar orbit insertion
- Approximately 28 day lunar polar orbit flight

Subsystem	Modifications	Test Requirements
Struct.	• Replace descent stage with low profile structure • Add micrometeoroid protection • Add supp't struct. for exper. and FCA subass'y • Add support structure for radiator • Add viewfinder port.	• Des., dev., & qual. low profile descent stage. • Demonstrate adequacy of stand-offs • Demonstrate support structure integrity • Demonstrate viewfinder port struct. integrity and leakage
S & C	• Add horiz. sensor for attitude reference. • Modify AEA and ASA	• Verify intermittent long duration operational cycles. • Integrate horiz. sensors into subsys. • Qual horiz. sensors • Verify modified AEA and ASA operations
Crew Prov., ECS, EPS, Instr., Comm., Cont. & Disp.	• Same as config. 1	• Same as config. 1
N & G, RCS, Ldg. Gear, Propul.	• Delete	

TABLE 2.1-3

SHELTER

CONFIGURATION 1

Mission Profile

- Apollo mission to separation in lunar orbit
- Automatic unmanned landing
- Three days semi-active operation
- Approximately 12-1/2 days active utilization

Subsystem	Modifications	Test Requirements
Structure	• Add micrometeoroid protection • Add support struct. for payload, subsys & exper. • Add insulation	• Demonstrate adequacy of standoffs • Demonstrate support structure integrity • Verify thermal control in system tests
S & C	• Delete abort guidance sys.	• Verify electronic sys. integrity
G & N	• Replace AOT with star tracker* • Add star catalog data to LGC* • Delete R.R.	• Des, dev. & qual. auto. star tracker* • Verify electronic sys. integ. • Verify computer programming
Crew Provisions	• Add LiOH & food (GFE): provides sleeping facilities & experiment work areas. • Provide increased hygiene facilities • Add spare space suits & back packs • Provide exercise facilities	• Verify adequacy of containers to withstand extended exposure. • Demonstrate integrity of additional components • Verify extended operating life of waste management equipment
ECS	• Add GOX and water tanks • Provide additional cold plates for batteries • Modify coolant circulation pumps and distr. sys.	• Verify extended operating life • Demonstrate integration of additional components into system • Requalify circulation pump and coolant distribution system
Landing Gear	• No change	

* May be accomplished on the LEM program.

TABLE 2.1-3 (cont)

Subsystem	Modifications	Test Requirements
Instrumentation	• Delete ascent monitor functions • Provide capability to accept scientific data; add programmer and CSM tape recorder	• Verify extended operating life • Demonstrate electronic sys. integration
EPS	• Add batteries	• Demonstrate integration of additional batteries • Verify extended operating life
Propul.	• Provide vent for descent tanks • Delete ascent propulsion	• Verify integrity of vent subassy • Verify vent integration into system
RCS	• Provide vent for tanks • Delete one pressurization and propellant storage module • Provide insulation covers for clusters	• Verify integrity vent subass'y • Verify system integrity • Verify capability of insulation covers to provide required thermal control. • Verify integrity of cover deployment mechanisms
Comm	• Add wide band receiver for EVA TV	• Qual. new receiver • Verify extended operating life • Demonstrate integration of receiver into sys.
Controls & Displays	• Delete att & trans. controller and descent status & display panels.	• Verify extended operating life of gauges and switches remaining

TABLE 2.1-4

SHELTER

CONFIGURATION 2

Mission Profile

- Apollo mission to separation in lunar orbit
- Automatic unmanned landing
- Up to 45 days quiescent storage on lunar surface
- Remote activation and checkout
- Approximately 14 days active utilization

Subsystem	Modifications	Test Requirements
Struct.	• Add micrometeoroid protection • Add support structure subassy's for exper & subsys. mods • Add insulation	• Demonstrate support struct integrity • Demonstrate adequacy of standoff structure • Verify material stability for prolonged lunar surface environment
S & C and N & G	• Same as config. 1	• Same as config. 1
Crew Provis.	• Add LiOH and food (GFE) • Provide sleeping facil., & exper. work areas • Provide hygiene facilities • Add space suits and back packs	• Verify extended storage capability under varying ambient environment up to 45 days, & subseq. operation for extended duration. • Qualify additional subass'y
ECS	• Add radiator • Substitute water management with item from CSM	• Des., dev & qual a radiator • Integrate radiator into heat transport loop & water management system • Verify extended storage capability under varying ambient environment up to 45 days & subseq. operation for extended duration.
Landing Gear	• No change	

TABLE 2.1-4 (cont)

Subsystem	Modifications	Test Requirements
Instr.	• Same as config. 1 and add remote activation and on board check system	• Same as config. 1 • Des., dev. & qual activation and checkout subass'y.
EPS	• Delete all but one ascent battery • Add restartable FCA's and cryogenics • Add RTG subass'y	• Demonstrate storage and remote startup of FCA's • Demonstrate cryogenic storage up to 45 days lunar surface environment • Integrate RTG into distribution system • Verify subsystem extended storage & subseq. operation for extended duration.
Propul & RCS	• Same as config. 1	• Same as 1
Comm.	• Same as config. 1	• Qual. new receiver • Verify subsys. extended stor. & subseq. operation for extended duration
C & D	• Same as config. 1	• Verify extended storage & operation

TABLE 2.1-5

SHELTER

CONFIGURATION 3

Mission Profile

- Apollo mission to separation on lunar surface
- Automatic unmanned landing
- Up to 90 days quiescent storage on lunar surface
- Remote activation and checkout
- Approximately 14 days active utilization

Subsystem	Modifications	Test Requirements
Struct.	• Same as config. 2	• Same as config. 2
S & C and N & G	• Same as config. 2	• Same as config. 2
Crew Prov.	• Same as config. 2	• Same as config. 2
ECS	• Add Radiator • Integrate Gemini fuel cell H_2O management equip.	• Des., dev & qual a radiator • Integrate radiator into heat transport loop & H_2O management system. • Verify extended storage capability under varying ambient environment up to 90 days & subseq. operation for extended duration
Landing Gear	• No change	
Instr.	• Same as config. 2	• Same as config. 2

TABLE 2.1-5 (cont)

Subsystem	Modifications	Test Requirements
EPS	• Delete all but one ascent battery • Add restartable Gemini FCA's • Add RTG subass'y. • Design & integrate ambient reactant tanks.	• Demonstrate storage & remote startup of FCA's. • Qual. ambient reactant tanks • Integrate RTG into distribution system. • Verify subsystem extended storage & subseq. operation for extended duration.
Propul & RCS	• Same as config. 2	• Same as config. 2
Comm.	• Same as config. 2	• Same as config. 2
C & D	• Same as config. 2	• Same as config. 2

TABLE 2.1-6

TAXI

CONFIGURATION 2

Mission Profile

- Apollo mission to lunar touchdown
- Approximately 14-day quiescent storage day and 7-day quiescent storage night
- Apollo ascent and rendezvous

Subsystem	Modification	Test Requirements
Structure	• Add insulation around water tanks and batteries • Add top hatch thermal shield • Add window shades • Provide increased micrometeoroid protection • Modify battery support structure	• Static and dynamic qualification additional structural elements • Static and dynamic tests of thermal shield standoffs • Thermal vacuum test of thermal shields and window shades
Landing Gear	• No change	
ECS	• Add IMU, ASA coolant bypass	• Qualify modification components • Endurance test of subsystem for operation during storage • Integration tests of coolant subassembly modifications
EPS	• Provide provisions for varying battery quantity from 4 to 7	• Endurance and cycle tests of components • System integration bench tests to demonstrate variable power generation configuration
Comm.	• No change	• Qualify components in S-band section for endurance and cyclic operation • Extended storage and operation tests of other sections
Instr.	• Add automatic switches for periodic status monitoring and real time communications • Add sequencer to activate elements	• Qualify sequencer and switches • Integrate components into subsystem • Demonstrate 14 day intermittent operation to critical mission profile.

TABLE 2.1-6 (cont)

Subsystem	Modification	Test Requirements
RCS	• Provide thruster covers	• Thermal vacuum tests of covers • Deployment and retraction tests • Demonstrate subsystem operation subsequent to 14 day storage under pressure
Propulsion	• Add vent valve to descent system	• Qualify (dynamic ambient environment) vent valve • Demonstrate operation and integration of valve into subsystem • Demonstrate storage & performance of ascent subsystem in ambient environment
Crew Provisions	• Remove LiOH canisters, food and spare backpack batteries	
Controls Displays	• No change	• Demonstrate subsystem performance subsequent to 14 day quiescent storage in the simulated environment
N & G	• Software change to LGC for rendezvous radar to surface beacon for descent control.	• Verify software mods in flight control integration laboratory • Demonstrate subsystem performance after 14 day storage in the simulated environment
S & C	• No change	• Demonstrate subsystem performance after 14 day storage in the simulated environment

TABLE 2.1-7

TAXI

CONFIGURATION 5

Mission Profile

- Apollo mission to lunar touchdown
- Approximately 14 day quiescent storage day and/or night
- Apollo ascent and rendezvous

Subsystem	Modifications	Test Requirements
Structure	• Add insulation around water tanks and batteries • Add top hatch thermal shield • Add window shades • Provide increased micrometeoroid protection • Provide RTG & Heat Pipe support structure	• Static and dynamic qualification additional structural elements • Static and dynamic tests of thermal shield standoffs • Thermal vacuum tests of thermal shields and window shades
Landing Gear	• No change	
ECS	• Add IMU and ASA coolant loop by pass • Integrate Heat Pipe into cabin thermal control system	• Qualification of modifications components • Endurance test of subsystem for operation during storage • Integration of heat pipe into thermal control system in system T/V tests • Qualification of heat pipe components • Integration tests of coolant subassembly modifications in subsystem performance tests.
EPS	• Add RTG subassembly • Modify electrical distribution system to permit RTG to charge descent battery • Remove batteries	• Qualification RTG subassembly • System integration tests to demonstrate performance and recharging capacity • Subsystem endurance tests

TABLE 2.1-7 (cont)

Subsystem	Modifications	Test Requirements
Comm.	• Same as configuration 2	• Same as configuration 2
Instr.	• Same as configuration 2	• Same as configuration 2
RCS	• Same as configuration 2	• Same as configuration 2
Propulsion	• Same as configuration 2	• Same as configuration 2
Crew Provisions	• No change	
Controls and Displays	• Same as configuration 2	• Same as configuration 2
N & C	• Same as configuration 2	• Same as configuration 2
S & C	• No change	• Same as configuration 2

TABLE 2.1-8
TRUCK
CONFIGURATION 1

Profile

- Apollo mission to lunar orbit coast
- Remote activation and checkout
- Automatic unmanned landing

Subsystem	Modification	Test Requirements
Structure	• Add support struct. to des struct. • Provide rigid navigation base	• Verify struct integ. support structure • Verify rigidity of navigation platform relation to RCS and descent engine
S & C	• Delete abort guidance	• Verify reconfigured subsystem electronic integrity
G & N	• Replace AOT with auto tracker assembly • Relocate subsys. components • Add star catalog data to LGC	• Des. dev. & qual auto tracker assembly • Verify electronic sys. integration • Demonstrate programming changes are compatible with LGC
Crew Provisions	• Delete	
ECS	• Reconfigure heat transport loop • Relocate cold plates	• Verify subsys. integration and performance
Ldg. Gr.	• No change	
Instr.	• Reconfigure subsys. • Delete some sensors, tape recorder, & one SCU • Provide activation checkout Programmer • Relocate subsystem components	• Verify subsys configuration • Des., dev. & qual activation & checkout programmer
EPS	• Delete descent batteries • Provide one ascent battery • Reconfigure distr. sys. • Modify electro pyro sys.	• Verify distribution system integrity & performance • Verify electro pyro sys. integrity • Demonstrate battery performance against worst case power profile and peak load condition

TABLE 2.1-8 (cont)

Subsystem	Modification	Test Requirements
Propul	• Provide vent for desc. tanks	• Qualify vent valve • Verify vent integration
RCS	• Provide vent for tanks • Relocate RCS lines and clusters, and provide one propellant pressurization system	• Verify vent integration • Demonstrate verify subsystem performance capability
Comm	• Relocate S-band & VHF system • Relocate antennas	• Verify subsys. electronic integration • Verify antenna patterns
Controls and Displays	• Delete	

* Subsystems relocated from the ascent stage to the descent stage may require requalification for the dynamic and ambient environment because of changes in support structure and thermal environment of compartment.

3 SYSTEM DEVELOPMENT

3.1 INTRODUCTION

This section describes the system development tasks related to the eight conceptual configurations analyzed.

3.2 CONFIGURATION DESCRIPTION

The general description of each of the conceptual designs highlights the primary differences. It is recognized that at lesser levels of assembly and fabrication additional significant changes will occur. These differences will be delineated in subsequent phases of the study.

3.2.1 Lab Configuration 1

This configuration consists of the LEM ascent and descent structure with the large panoramic cameras located on the sides of the ascent stage. The descent propulsion system is retained for lunar orbit abort. The RCS and N & G subsystems and the landing gear are deleted. The S & C subsystem are deleted with the exception of the DECA. All guidance and control functions are performed by the GNCS aboard the CSM, including long term attitude reference sensors systems.

All sensors and SCU's associated with deleted subsystems are also removed and the experiment data is integrated into the PCMTE for taping on a modified Gemini recorder and/or transfer to the CM communications subsystems. The CM to LEM intercomm is the major component of the LEM communication subsystem retained. The electrical power subsystem batteries are replaced with fuel cell assemblies which for the purpose of this volume are assumed to be CSM FCA's qualified for 1,000 hours and capable of in-flight start up. The cryogenics tanks are Apollo-X configurations as designed and developed for the CSM. The ECS system is a closed loop system for the FCA's and the heat transport section with radiators and supplemental water boilers. The waste management section is deleted from the crew provisions subsystem and additional LiOH canisters and GFE food are added. The controls and displays associated with the deleted subsystems are removed. The EPS panel is reconfigured for the new generation section, and the front and right side panels are modified to incorporate work areas for the experiments.

3.2.2 Lab Configuration 2

This configuration consists of the LEM ascent stage and a new low profile descent stage with the two large panoramic cameras suspended from the lower deck of the descent stage. The propulsion, RCS and N & G subsystems, and the landing gear are deleted. The S & C subsystem is modified with the addition of a horizon scanner and modifications to the ASA and AEA to provide the error signal to the CSM RCS for attitude control during the mapping mission. All sensors and SCU's associated with deleted subsystems are also removed and the experiment data are integrated into the PCMTE for taping on a modified Gemini recorder and/or transfer to the CM communications system. The CM/LEM intercomm is retained.

The EPS, ECS, Controls & Displays, and Crew Provisions subsystems are identical to Configuration 1.

3.2.3 Shelter Configuration 1 - Consists of the LEM ascent and descent stages with the capability for accomplishing an automatic unmanned landing added and ascent capability deleted. Additional quantities of batteries, O_2, food, LiOH, and water are provided for the extension of the lunar stay duration. A VHF receiver is required to allow reception of TV from the EVA. A CSM tape recorder is required for data management. Sleeping and hygienic facilities, experiment work areas, vents for the RCS and propulsion tanks are added.

3.2.4 Shelter Configuration 2 - Consists of the LEM ascent and descent stages with the capability for accomplishing an automatic unmanned landing added and ascent capability deleted. The extension of lunar stay and quiescent storage is accomplished by adding a radiator with water boiler supplement to the ECS heat transport section, replacing the EPS battery generation system with restartable CSM FCA's and providing Apollo-X type cryogenic tanks for the reactants. All other modifications are similar to Configuration 1.

3.2.5 LEM Shelter Configuration 3 - Consists of the LEM ascent and descent stages with the capability for accomplishing an automatic unmanned landing added and ascent capability deleted. The extension of lunar stay and quiescent storage has been accomplished by adding a radiator with water supplement to the ECS heat transport section, replacing the EPS battery generation system with restartable Gemini FCA's and providing ambient reactant tanks. All other modifications are similar to configuration 2.

3.2.6 Taxi Configuration 2 - Consists of the basic LEM spacecraft modified to allow quiescent storage for up to 14 days (only 14-day day mission). The descent battery configuration is modified to provide the flexibility of carrying four or seven descent stage size batteries (the required quantity is dependent upon the day/night stay period). The following modifications are required for both configurations: add additional micrometeoroid protection, provide a thermal shield for the upper hatch, provide window shades, provide covers for the RCS thruster quads, modify the ECS glycol loop to bypass the IMU and ASA and also change the cooling sequence, change descent stage water tank structure and add insulation around water tank, add switches and programmer for periodic status monitoring, change battery supports and add insulation around batteries, add heater to descent stage water tank, delete the scientific payload and some of the LiOH canisters, food, and backpack batteries.

3.2.7 Taxi Configuration 5 - Consists of the basic LEM spacecraft modified to allow quiescent storage for up to 14 days. The descent battery subassembly is decreased to three batteries. In addition to the modifications described for Configuration 2, one or two RTG's (dependent upon day or night mission) are integrated into the spacecraft EPS and ECS subsystem to supplement the battery power supply during the quiescent period and to provide thermal energy to the cabin through a heater system.

3.2.8 Truck Configuration 1

This configuration consists of the LEM descent stage structure, propulsion subsystem and landing gear with additions from subsystems located in the ascent stage to permit an automatic unmanned descent and landing on the lunar surface from lunar orbit. One section of the RCS pressurization and propellant storage and the four quad clusters from the ascent stage are relocated on the descent stage. Components of the S & C and N & G subsystem required for descent are located in the descent stage. This includes an automatic star tracker with associated electronics, which replaces the alignment optical telescope. A single ascent stage battery replaces the four batteries normally located in the descent stage, and an ECS heat transport loop for active thermal control is included. Instrumentation and communication components as required for activation, checkout, and status monitoring during descent are located in the descent stage.

3.3 AES DEVELOPMENT PROGRAM

For this analysis, the AES development program is separated into the following levels of testing:

- Subsystems Development
- Combined Subsystems Development
- System Verification
- Experiment Payload Integration
- AES Flight Missions

The first and last two items are presented in the charts largely for reference purposes and to define constraints. Combined subsystems development and system verification are examined in depth in the following paragraphs.

3.3.1 Discussion

The Ground Test Logic Charts define the development and verification test programs for each of the configurations plus one for the Lab, Shelter, and Taxi combined. These charts reflect the current Apollo Schedule 37, and a summary of the major test facilities required appears on each chart. The tables at the end of this section present a detailed description of the test articles and facilities, test objectives, and commonality with existing LEM test articles and facilities.

3.3.2 Lunar Orbiting Laboratory

Both L. O. Lab configurations require complete electronic, thermal, and structural development and verification test programs, because of the changes in the EPS, ECS, and the structural support of equipment. The Ground Test Logic Charts, Fig. 3-2 and Fig. 3-3 show that the difference between the two configurations lies in the additional static tests required to verify the Low Profile Descent Stage (LPDS) for launch and boost loading conditions and to gain elastic deflection data for optical alignment requirements. Refer to the Test Article descriptions in Tables 3.3-1 and 3.3-2 for further details. It is noted that neither configuration requires Flight Control Integration (FCI) testing since they do not have RCS or propulsion except for the Configuration 1 descent engine, which is controlled from the CSM.

3.3.3 Shelter

Configuration 1 requires a minimum of structural and electronic development testing with the necessary modifications being verified by structural and electronic integration tests, both performed on one test article, SLTA-1, as shown in Fig. 3-4. The 14-day active lunar stay, however, requires thermal development testing with a modified TM-2 from LEM, as well as verification thermal-vacuum tests at MSC.

The additional structural and electrical modifications for the ECS radiator and EPS fuel cells of Configuration 2 are also verified with one test article, since commonality with the Lab in these subsystems reduces the Shelter integration testing. However, the ECS and EPS modifications of Configurations 2 and 3, and the extended lunar storage before activation requires extensive thermal development. Here, additional modification and thermal-vacuum testing of the TM-2 from the LEM is shown in Fig. 3-5, and 3-6, and a power generation thermal test program is added. The ECS and EPS thermal development test results are verified at MSC as for Configuration 1. Flight control integration programs are required for both configurations for the automatic unmanned landing verification. Refer to Tables 3.3-3, 3.3-4 and 3.3-5a for further details.

3.3.4 Taxi

The similarity in configuration and mission of the Taxi and the LEM permits a minimum of system level testing. Structural development and verification testing are performed on a structural element for both configurations. Thermal development tests of either the battery or the RTG configurations are conducted with minor modifications to the LEM TM-2 and verified by thermal-vacuum tests of a modified LEM LTA-8 at MSC as shown in Figs. 3-7 and 3-8. Electronic integration for either configuration is verified at MSC only using the modified LTA-8 and ACE, prior to thermal-vacuum tests. Tables 3.3-6 and 3.3-7 provide additional details. It is noted that flight control integration tests are performed for both configurations for the beacon landing system using rendezvous radar.

3.3-5 Truck

The Truck requires complete structural, electronic, and thermal development and verification testing programs as described in Fig. 3-9 and in Table 3.3-8.

3.3.6 Combined AES L.O. Lab, Shelter and Taxi

Fig. 3-1 presents the combined test programs for the Lab, Shelter, and Taxi. The progressive modification of common test articles and facilities is shown for overall comparison of the test programs for the selected configurations.

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No.	Task	1966 (months 1–6) / 1967 (months 7–18)
	GO-AHEAD	▲ (month 1)
1.0	SUBSYSTEM DEVEL.	PROVIDE PROTOTYPE LAB EQUIPMENT
2.0	COMBINED SUBSYSTEMS	
2.1	LM-1 EXT. MOCK-UP LAB.	DES / FAB / RADIATOR & FCA STUDY / EXPERIMENT STUDIES / SLA & GSE / COMBINE
2.2	LM-2 INT. MOCK-UP LAB.	DES / FAB / SUBSYSTEMS AND CONTR. & DISPLAYS / EXPERIMENTS & CONTR. & DISPL.
2.3	SM-1 EXT. MOCK-UP SHELT.	DES / FAB / EXPERIMENT LOCATION STUDIES / SLA & GSE / COM
2.4	SM-2 INT. MOCK-UP SHELT.	DES / FAB / SUBSYSTEMS LOCATIONS AND CONTROLS & DISPL. STUDIES
2.5	LTM-1 TEST MODEL (THERM) LAB	CSM SIMUL. FROM LEM / DESIGN ASC/LPDS / FAB ASC/LPDS / INSTALL HEATERS / INSTALL SIM. EQ. / REP / T/V DEV LUNAR
2.6	STM-1 TEST MODEL (THERM) SHELT.	TM-2 ASC. & DESC. FROM LEM / MOD. ASC/D FOR RADIATOR
2.7	TTM-1 TEST MODEL (THERM) TAXI	TM-2 ASC. & DESC. FROM LEM / MOD ASC/DESC FOR BAT.-RTG / REP / T/V DEV 2 WK STOR
2.8	TTE-1 TEST ELEMENT (STRUCT) TAXI	DES / FAB W/SIM. EQUIP / INST. / VIBR / STATIC
2.9	FCI FLT. CONTR. SIMUL.	SUBSYSTEMS FROM LEM / FCI TAXI BEACON LANDING / FCI SHELTER UNMANNED LANDING
2.10	IES INTERN. ENVIR. SIM.	MOD / LAB. MANNED OP
2.11	PGS POWER GENER. SIM.	DES THERM. MODEL / FAB THERM. MODEL / T/V
2.12	ESI-L HARNESS FAB, C/O	DES / FAB / BUILD-UP LTA-1 HARNESS & C/O / BUILD-UP HARNESS & C/O
2.13	ESI-S HARNESS FAB. C/O	DES / FAB / BUILD-UP HARNESS-C/O
2.14	ESI-T HARNESS FAB. C/O	ESI RIG FROM LEM
3.0	SYSTEM VERIFICATION	
3.1	LLTA-1 ELECT. VERIF. LAB	FAB ASC/LPDS / INTEGRATE SUBSYSTEMS / ACE
3.2	LLTA-2 ENVIRON. VERIF. LAB	FAB ASC/LPDS / INSTR / STATIC PROOF TESTS / INSTALL SIM. EQ. / VIB
3.3	SLTA-1 ELECTR. ENVIR. VERIF. SHELT.	FAB ASC/DESC / STAT / INSTALL SIM. EQ. / VIB / PROP
3.4	TLTA-1 ELECTR. ENVIR. VERIF. TAXI	LTA-8 AT MSC FROM LEM
4.0	AES MISSIONS	

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1968												1969															
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46

PROVIDE PROTOTYPE SHELTER EQUIP.

PROVIDE PROTO. TAXI EQUIP

PROVIDE QUALIFIED LAB EQUIP.

PROVIDE QUALIFIED SHELTER EQUIP.

PROVIDE QUALIFIED TAXI EQUIP.

& STUDY VARIOUS LAB OPERATIONS

BINE & STUDY LUNAR OPERATIONS AT "1/6 G"

EL. ORB. | MOD AS REQ'D | PREP | T/V DEVEL. FOR SUBSEQUENT LAB MISSIONS

ESC. & FCA | PREP | T/V DEVEL FOR 3 MOS. STORAGE

S. | MOD | SHELT. MANNED OPS

FCA LAB | MOD | T/V FCA FOR SHELTER 3 MOS. STORAGE

LTA-2 BUILD-UP HARNESS & C/O | LAB #1 | BUILD-UP HARNESS & C/O | LAB #2 | BUILD-UP HARNESS-C/O | LA #

LTA-1 | BUILD-UP HARNESS C/O | SHELT. #1 | BUILD-UP HARNESS + C/O | SHELT #2 | BU HA

MOD | BUILD-UP HARNESS & C/O | MOD KIT | BUILD-UP HARN & C/O | TAXI #1 | BUILD-UP HARNESS-C/O | TAXI #2

INTEG. EXPER. | EMC | ELECTRONIC INTEGRATION TESTS FOR SUBSEQUENT LAB MISSIONS

INSTALL SUBSYSTEMS & EXP | A C E | V I B | A C E | P/S | PREP & C/O | T/V L.O. CHAM "A" CSM | P/S | STRUCTURAL INTEGRATION TESTS FOR SUBSEQUENT LAB MISSIONS

INTEGRATE SUBSYSTEMS | A C E | INTEG EXP. | EMC | VIB | A C E | P/S | PREP & C/O | T/V 3 MO STOR CHAM "B" | P/S | STRUCTURAL & ELECTRONIC INTEG. TESTS FOR SUBSEQUENT SHELTER MISSIONS

LTA-B AT MSC FROM LEM | MOD. AT MSC | PREP | T/V 2 WK STOR CHAM "B"

FAB ASC. | FA | FAB DESC | F.A. & C/O | P/S | ETR

FIRST L.O. LAB

FIRST SHELT

FIRST TAXI

2

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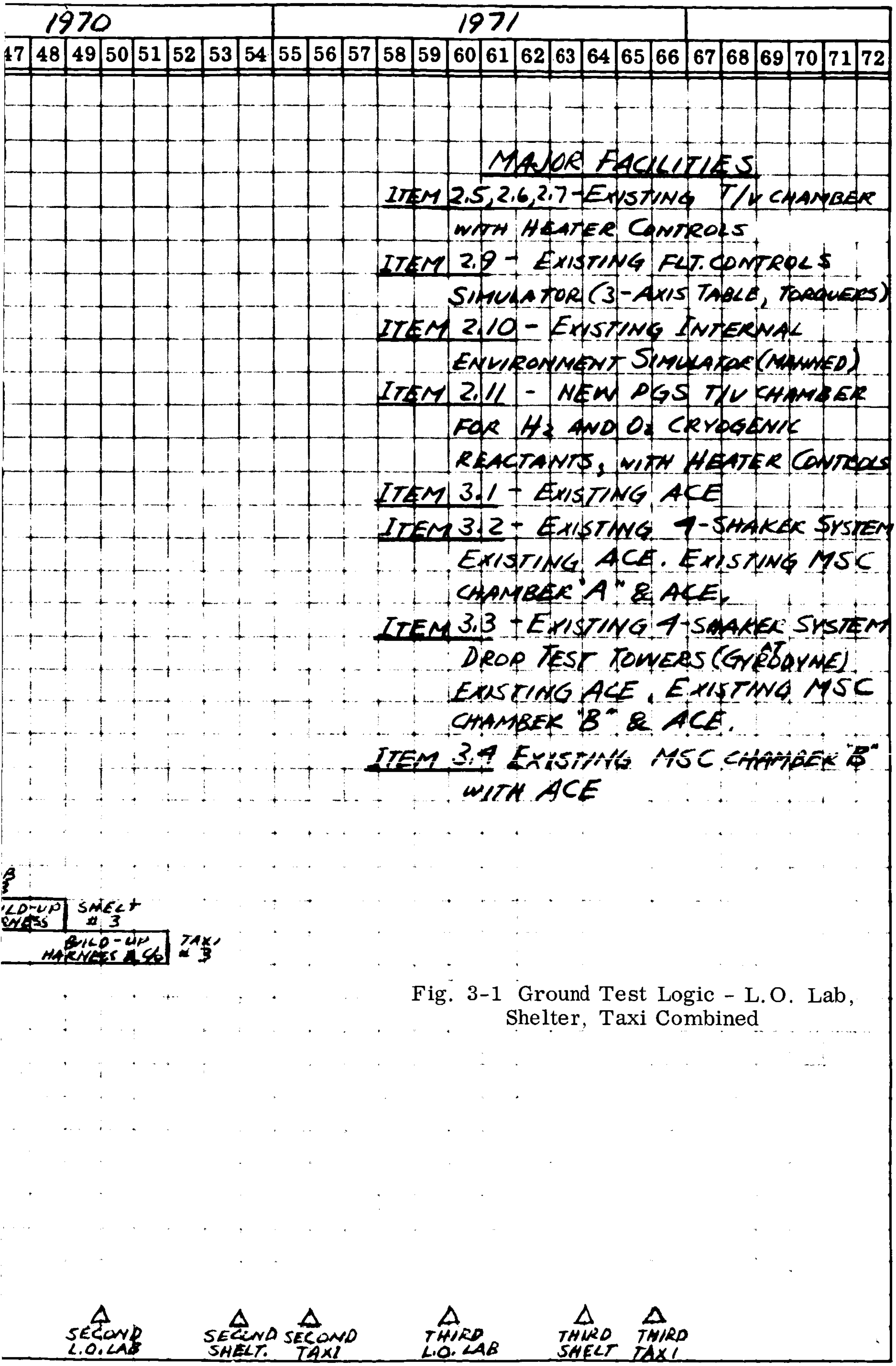
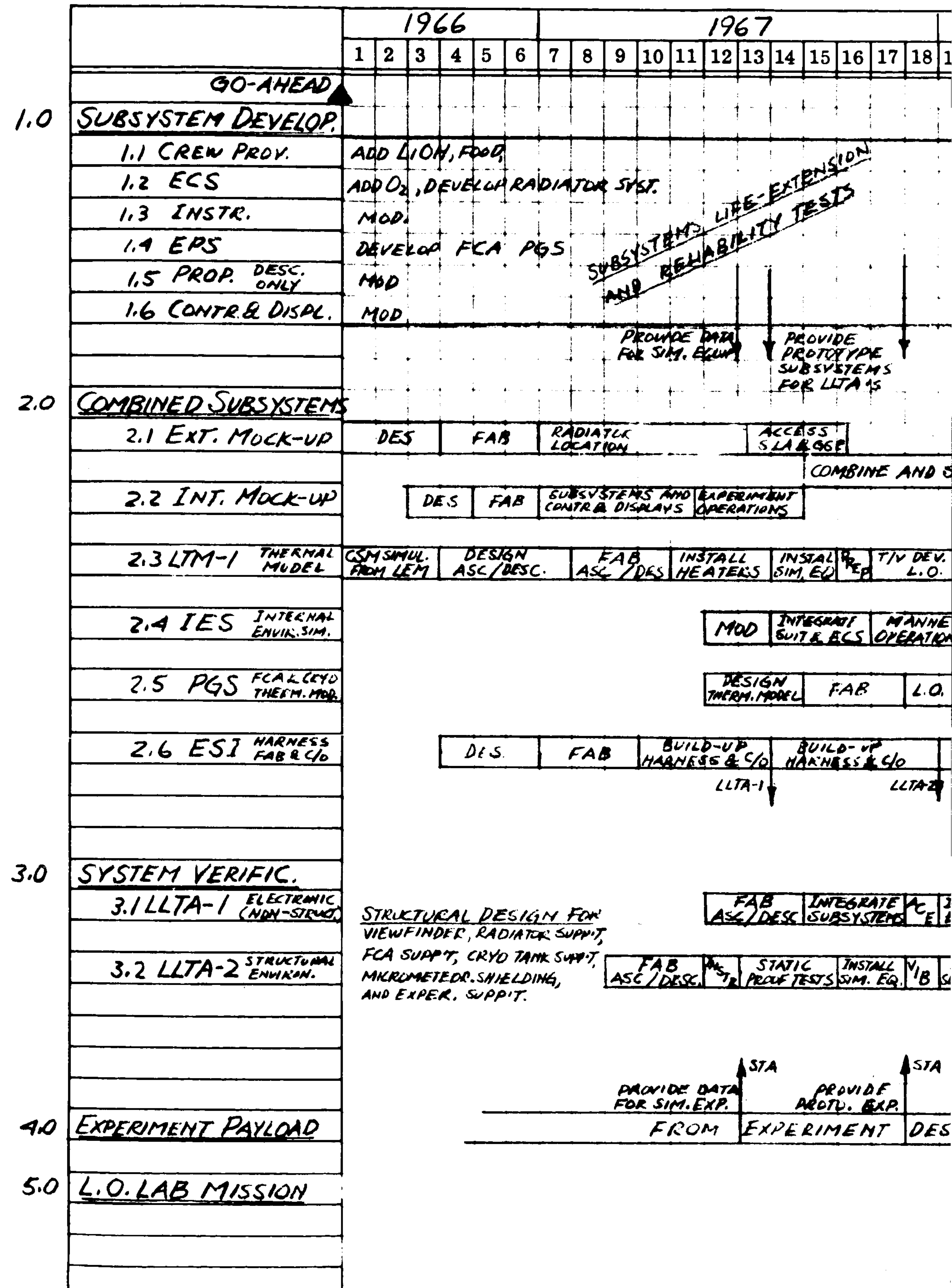


Fig. 3-1 Ground Test Logic - L.O. Lab, Shelter, Taxi Combined


1966
1967
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
GO-AHEAD
1.0 SUBSYSTEM DEVELOP.
1.1 CREW PROV.
1.2 ECS
1.3 INSTR.
1.4 EPS
1.5 PROP. DESC. ONLY
1.6 CONTR.& DISPL.
ADD LIOH, FOOD
ADD O_2, DEVELOP RADIATOR SYST.
MOD.
DEVELOP FCA PGS
MOD
MOD
SUBSYSTEMS LIFE-EXTENSION AND RELIABILITY TESTS
PROVIDE DATA FOR SIM. EQUIP.
PROVIDE PROTOTYPE SUBSYSTEMS FOR LLTA'S
2.0 COMBINED SUBSYSTEMS
2.1 EXT. MOCK-UP
DES
FAB
RADIATOR LOCATION
ACCESS SLA&GSE
COMBINE AND
2.2 INT. MOCK-UP
DES
FAB
SUBSYSTEMS AND CONTR.& DISPLAYS
EXPERIMENT OPERATIONS
2.3 LTM-1 THERMAL MODEL
CSM SIMUL. FROM LEM
DESIGN ASC./DESC.
FAB ASC./DES
INSTALL HEATERS
INSTAL SIM. EQ
T/V DEV. L.O.
2.4 IES INTERNAL ENVIR. SIM.
MOD
INTEGRATE SUIT & ECS
MANNED OPERATION
2.5 PGS FCA & CRYO THERM. MOD.
DESIGN THERM. MODEL
FAB
L.O.
2.6 ESI HARNESS FAB & C/O
DES.
FAB
BUILD-UP HARNESS & C/O
BUILD-UP HARNESS & C/O
LLTA-1
LLTA-2
3.0 SYSTEM VERIFIC.
3.1 LLTA-1 ELECTRONIC (NON-STRUCT.)
FAB ASC./DESC.
INTEGRATE SUBSYSTEMS
3.2 LLTA-2 STRUCTURAL ENVIRON.
STRUCTURAL DESIGN FOR VIEWFINDER, RADIATOR SUPP'T, FCA SUPP'T, CRYO TANK SUPP'T, MICROMETEOR. SHIELDING, AND EXPER. SUPP'T.
FAB ASC./DESC.
STATIC PROOF TESTS
INSTALL SIM. EQ.
STA
STA
PROVIDE DATA FOR SIM. EXP.
PROVIDE PROTO. EXP.
4.0 EXPERIMENT PAYLOAD
FROM
EXPERIMENT
DES
5.0 L.O. LAB MISSION

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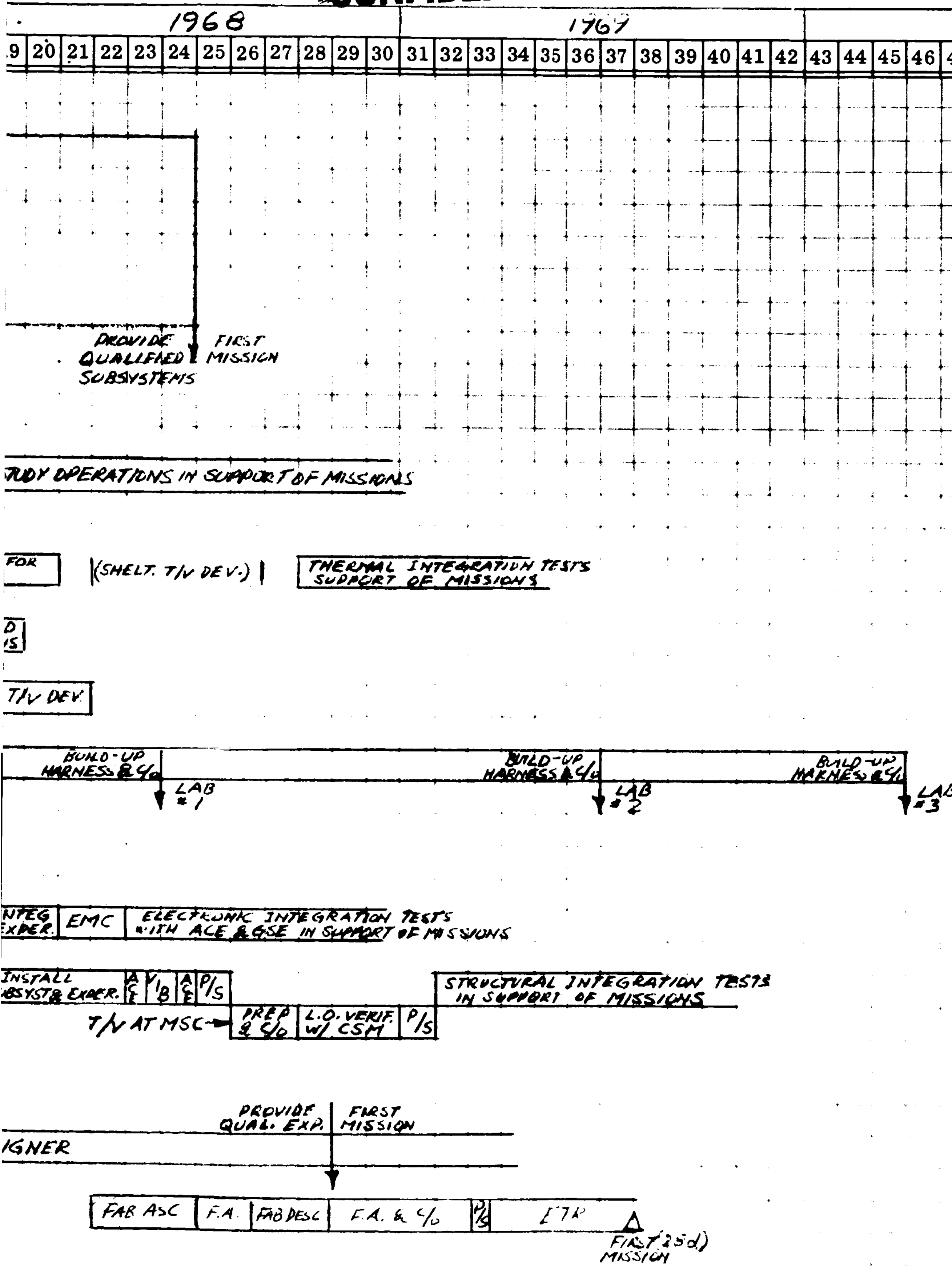

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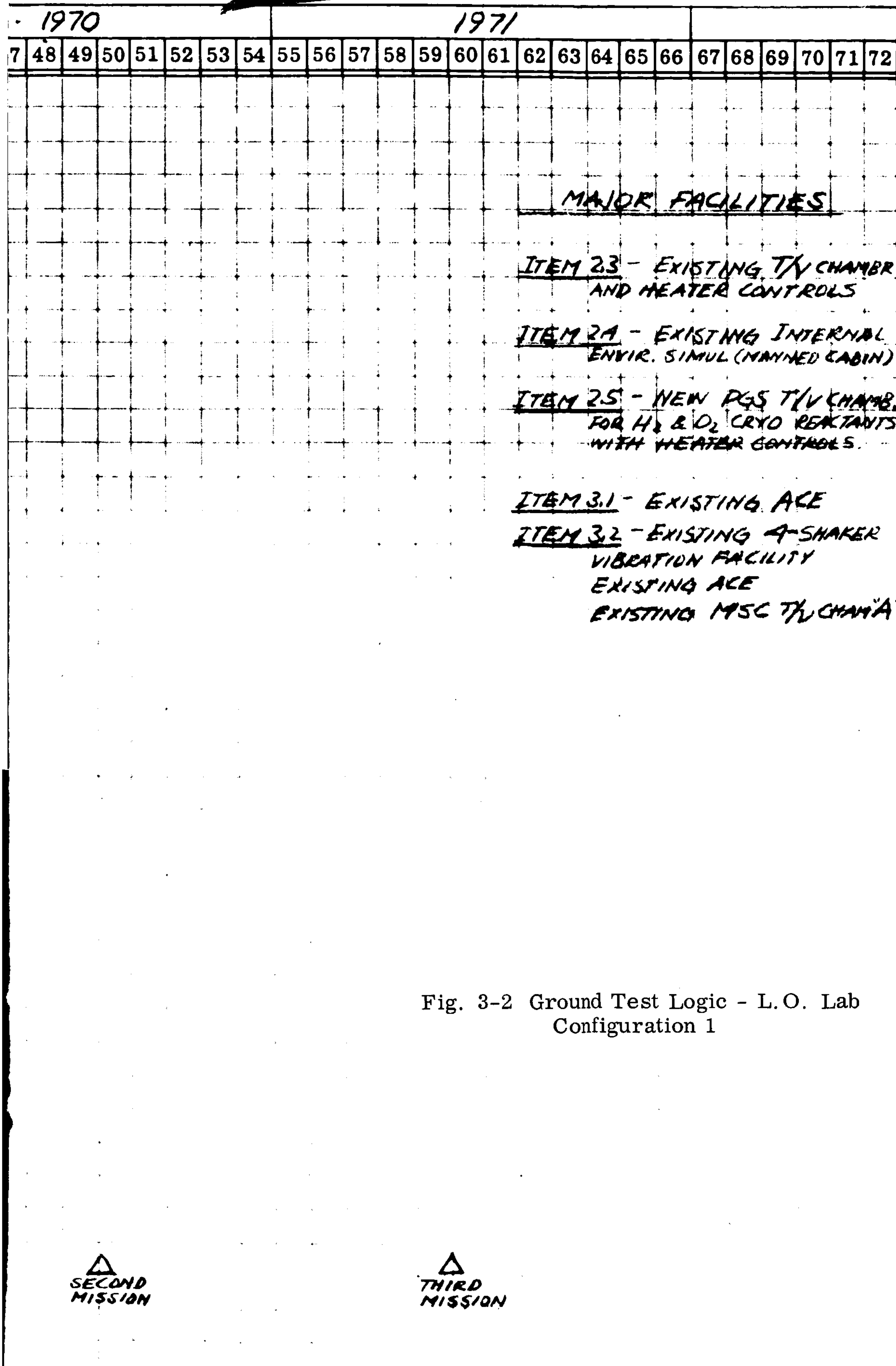

Fig. 3-2 Ground Test Logic - L.O. Lab Configuration 1

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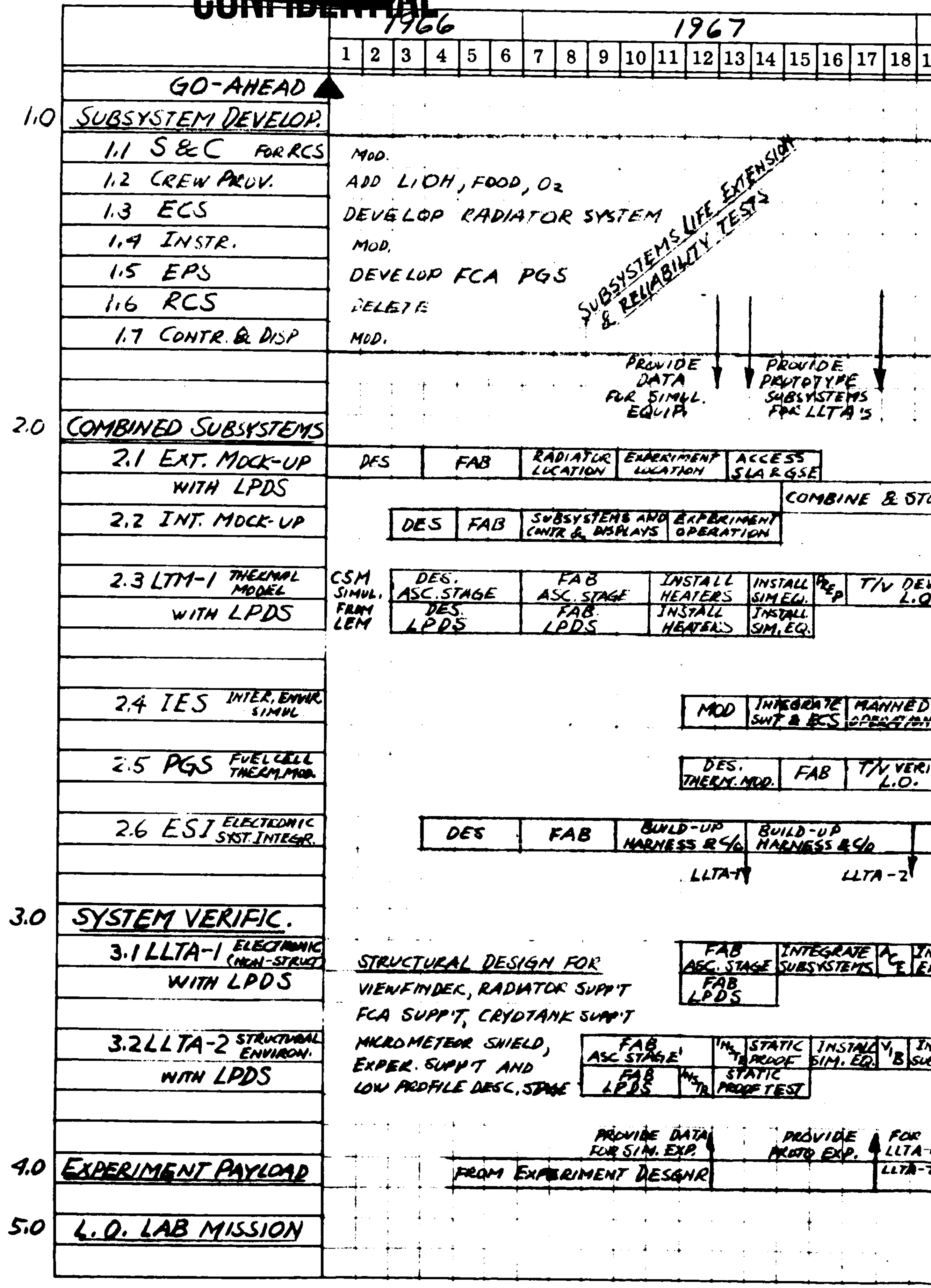

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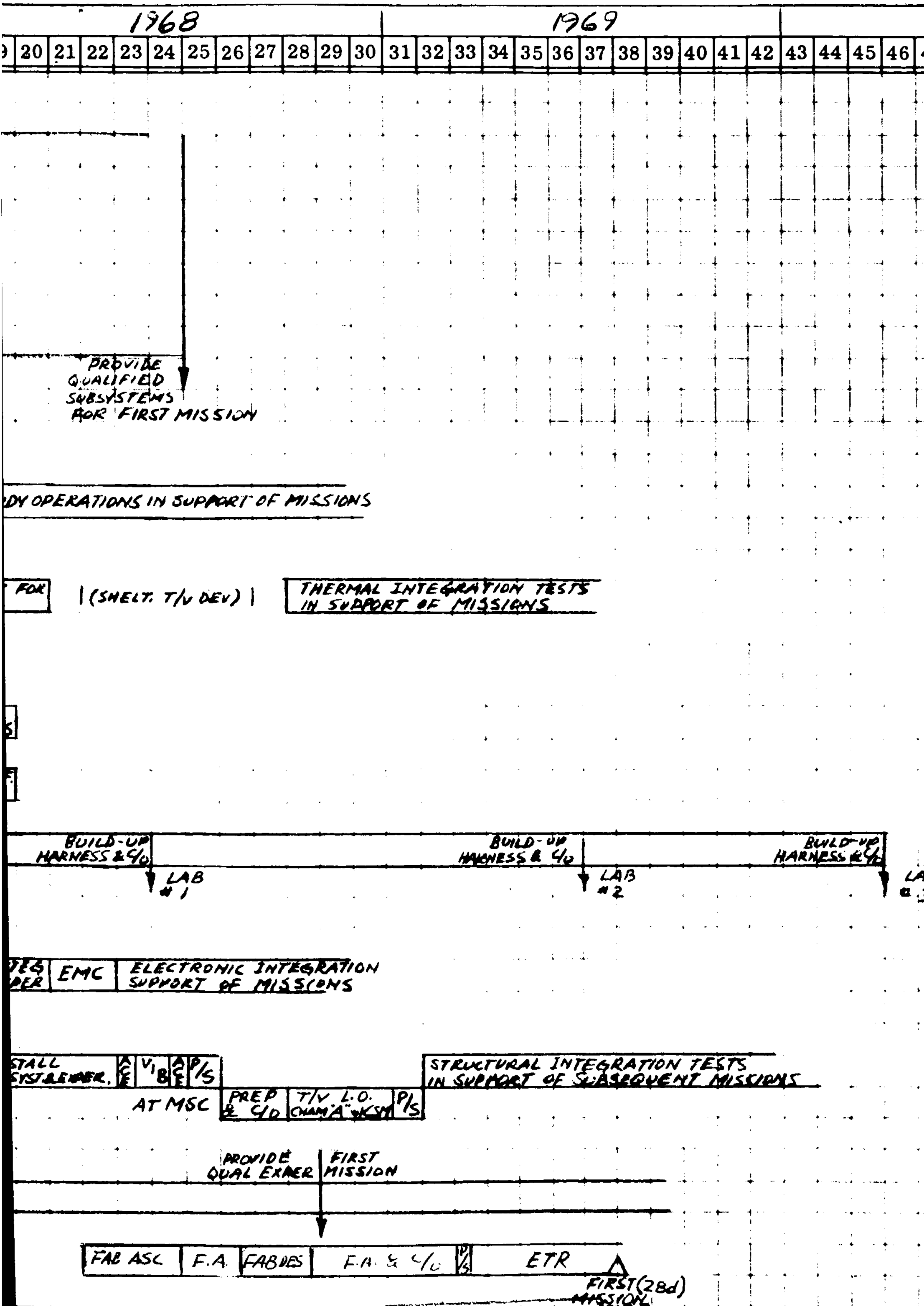

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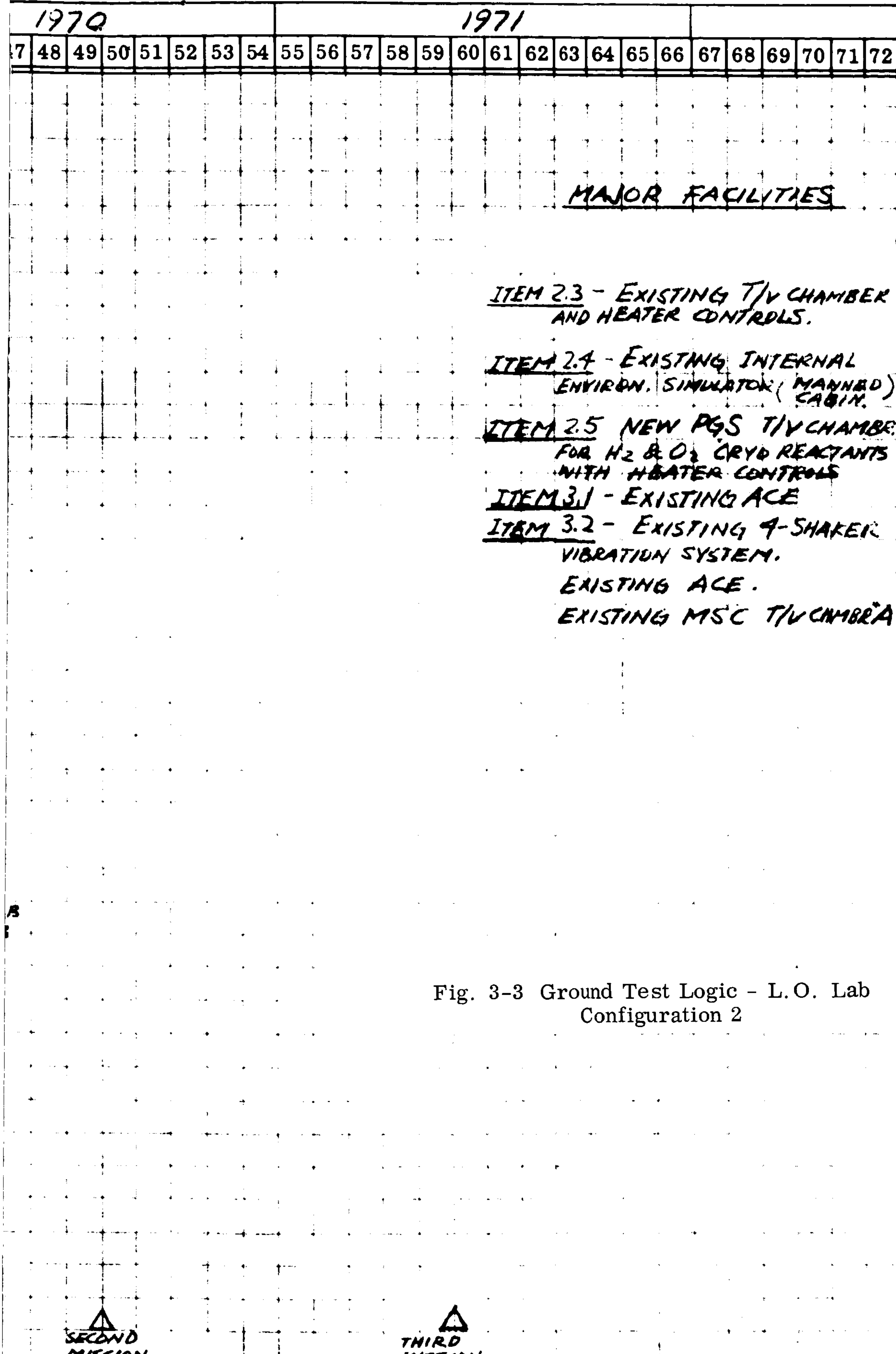

Fig. 3-3 Ground Test Logic - L.O. Lab Configuration 2

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	1966						1967											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

GO-AHEAD

1.0 SUBSYSTEM DEVELOP

1.1 G&N — DEV. UNMANNED LDG. SYSTEM

1.2 ECS

1.3 EPS

1.4 COMM. — TV RCVR.

1.5 INSTR.

1.6 C&D

1.7 CREW PROV

SUBSYSTEMS LIFE-EXTENSION FOR 14 DAY ACTIVE OPER. AFTER UNMANNED LANDING (NO QUIESCENT STORAGE)

PROVIDE DATA FOR MASS & THERM SIMULATORS

PROVIDE LDG. SYST. PROTO. FOR FCI

PROVIDE PROTO SUBSYSTEMS FOR SLTA

2.0 COMBINED SUBSYST.

2.1 EXT. MOCK-UP — DES | FAB | EXPERIMENT LOCATION STUDY | SLA & GSE | COMBIN…

2.2 INT. MOCK-UP — DES | FAB | SUBSYST & EXPER. LOCATION AND CONTROLS & DISPLAYS

2.3 STM-1 THERMAL MODEL — TM-2 ASC. & DESC. FROM LEM

2.4 FCI FLT. CONTR. SIMULATOR — FCI FOR UNMANNED LDG

2.5 IES INTERNAL ENV. SIMUL.

2.6 ESI HARNESS BUILD-UP & C/O — DES | FAB | BUILD-UP HARNESS & C/O

SLTA-1

3.0 SYSTEM VERIFIC

3.1 SLTA-1 ELECTR. ENVIRON. — FAB ASC/DESC | STAT | INSTALL SIM. LG | VIB | PROP

PROVIDE DATA FOR MASS & THERM. SIMUL.

4.0 EXPERIMENT PAYLOAD — DESIGN | DEVELOP

FROM EXPER. DESIGNERS

5.0 MISSION SHELTER /

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1

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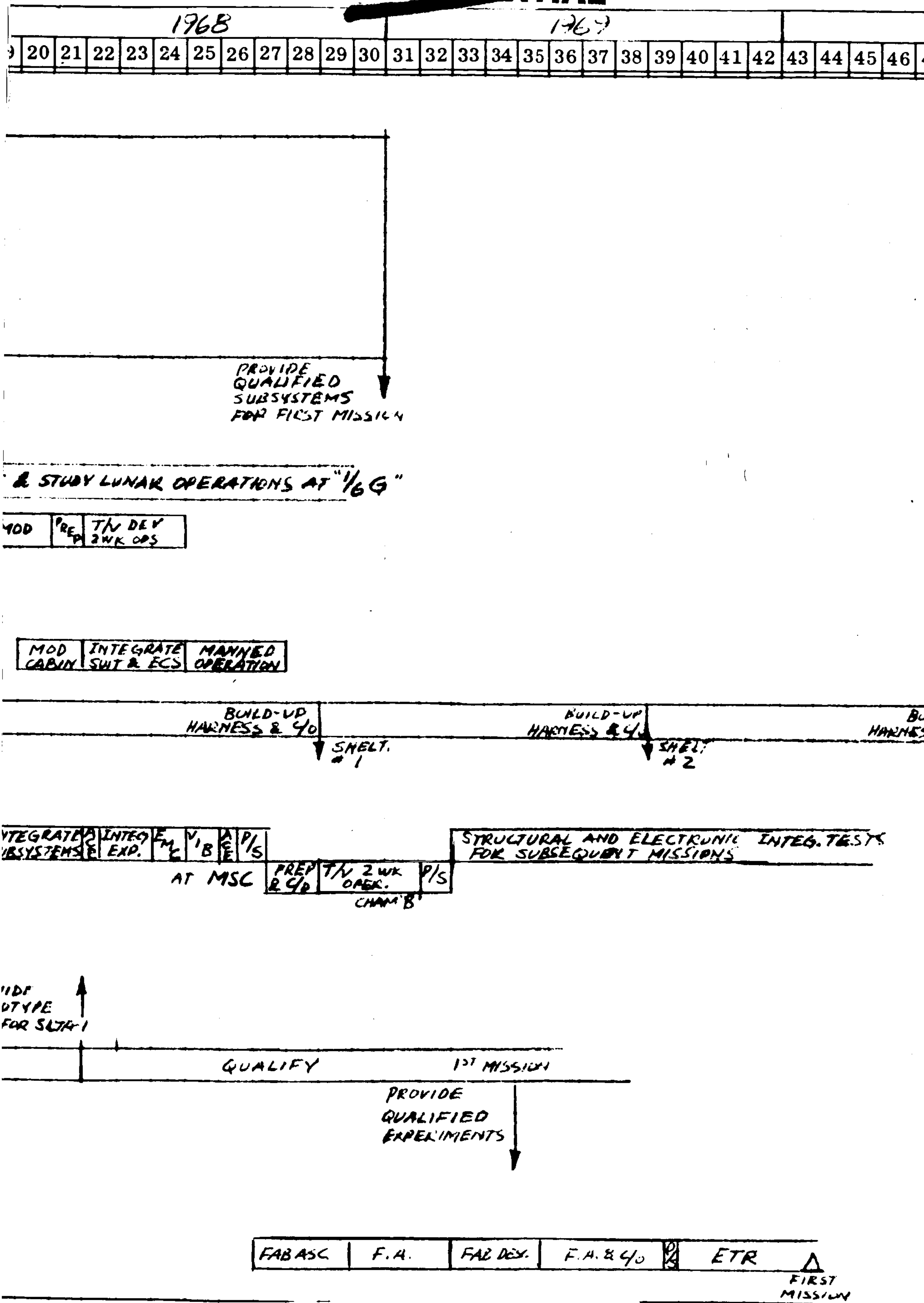

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2

1970								1971																		
47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72

MAJOR FACILITIES

ITEM 2.3 - EXISTING T/V CHAMBR AND HEATER CONTROLS

ITEM 2.4 - EXISTING FLT CONTR SIMULATOR (3-AXIS TABLE, TORQUERS)

ITEM 2.5 - EXISTING INTERNAL ENVIRON. SIMUL. (MANNED CABIN)

ITEM 3.1 - EXISTING 4-SHAKER SYST.
"EXISTING" DROP TOWER
EXISTING ACE
EXISTING MSC T/V CHAMB 'B'

SHELT #3

Fig. 3-4 Ground Test Logic - Shelter Configuration 1

SECOND MISSION

THIRD MISSION

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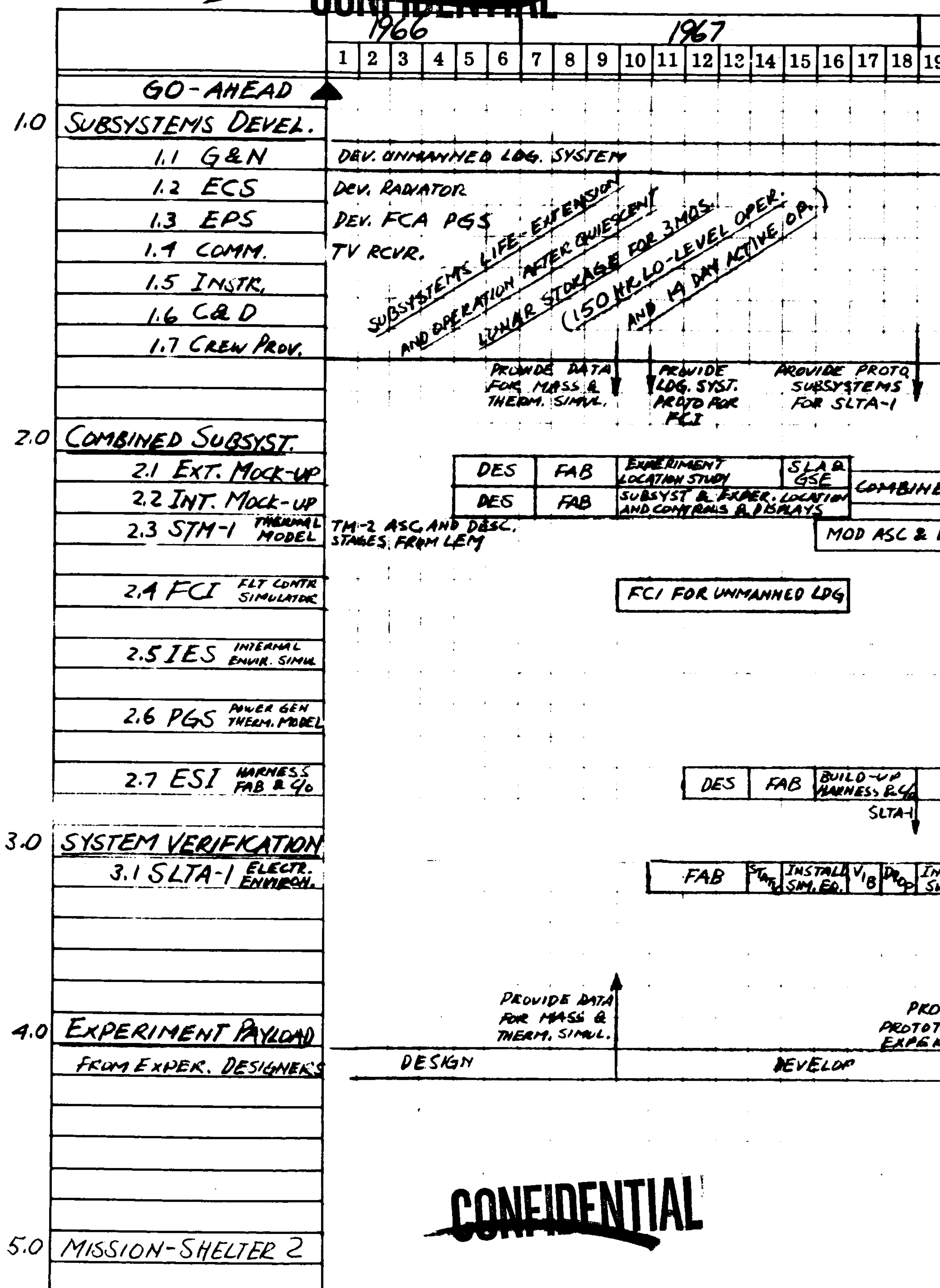

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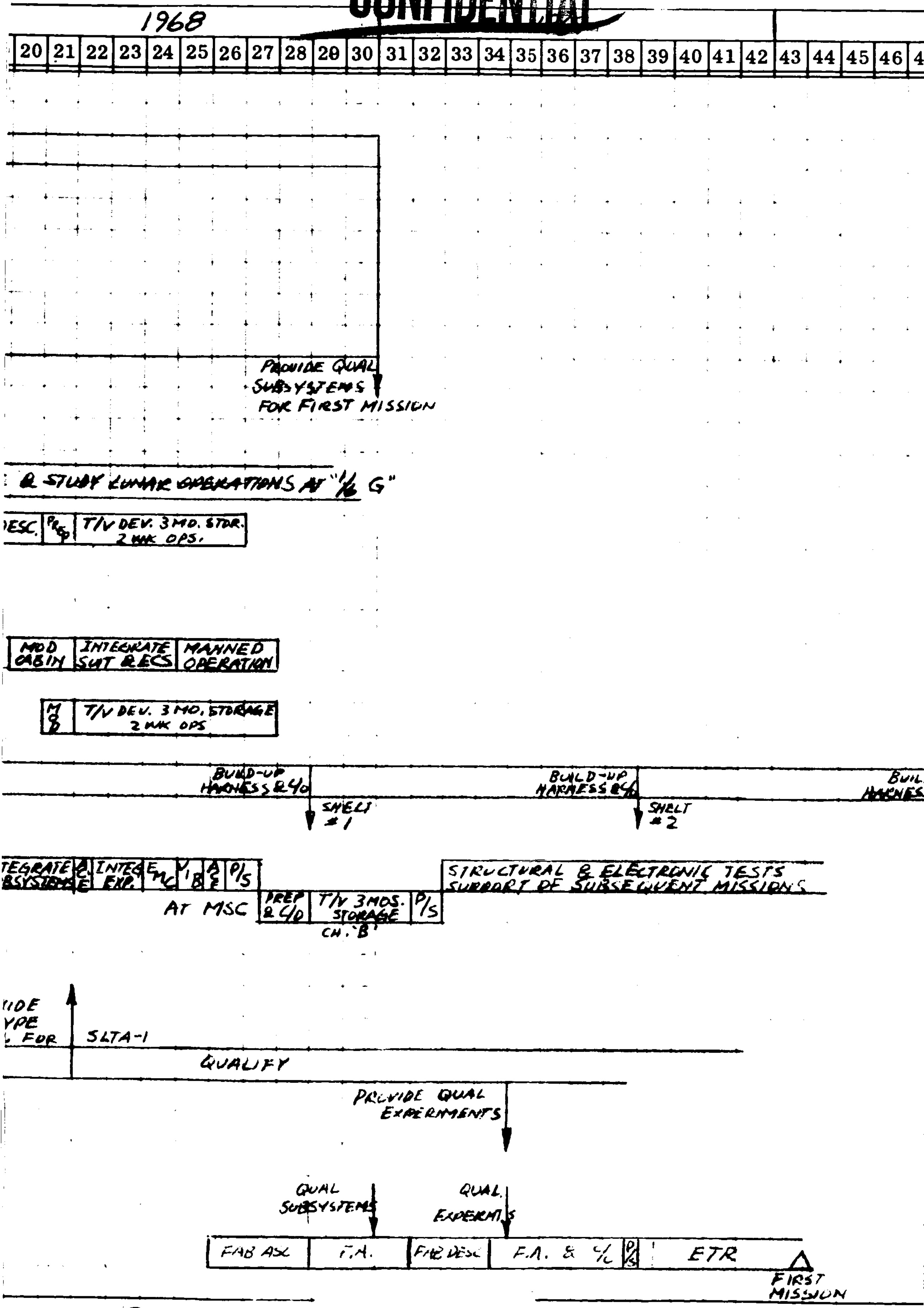

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1970										1971															
7	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72

MAJOR FACILITIES

ITEM 2.3 - EXISTING T/V CHMBR.
AND HEATER CONTROLS.

ITEM 2.4 - EXISTING FLT. CONTR.
SIMUL. (3-AXIS TABLE, TORQUER)

ITEM 2.5 - EXISTING INTERNAL
ENVIR. SIMUL. (MANNED CABIN)

ITEM 2.6 - NEW PGS T/V CHAMB.
FOR H_2 & O_2 CRYO REACTANTS
WITH HEATER CONTROLS

ITEM 3.1
EXISTING 4-SHAKER SYST.
"EXISTING" DROP TOWER
EXISTING ACE
MSC T/V CHAMBR 'B'

SHBL #3

Fig. 3-5 Ground Test Logic - Shelter Configuration 2

SECOND MISSION

THIRD MISSION

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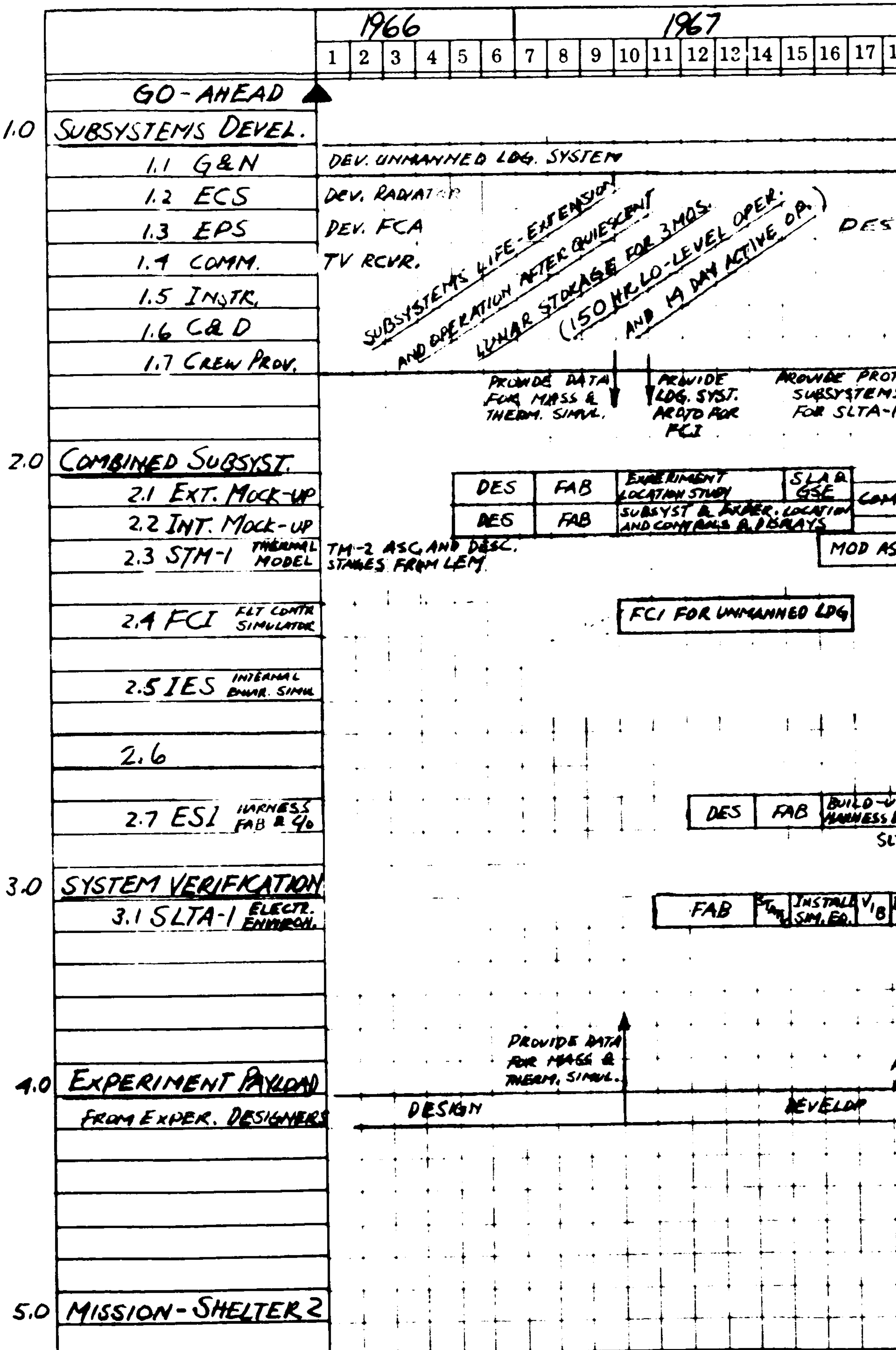

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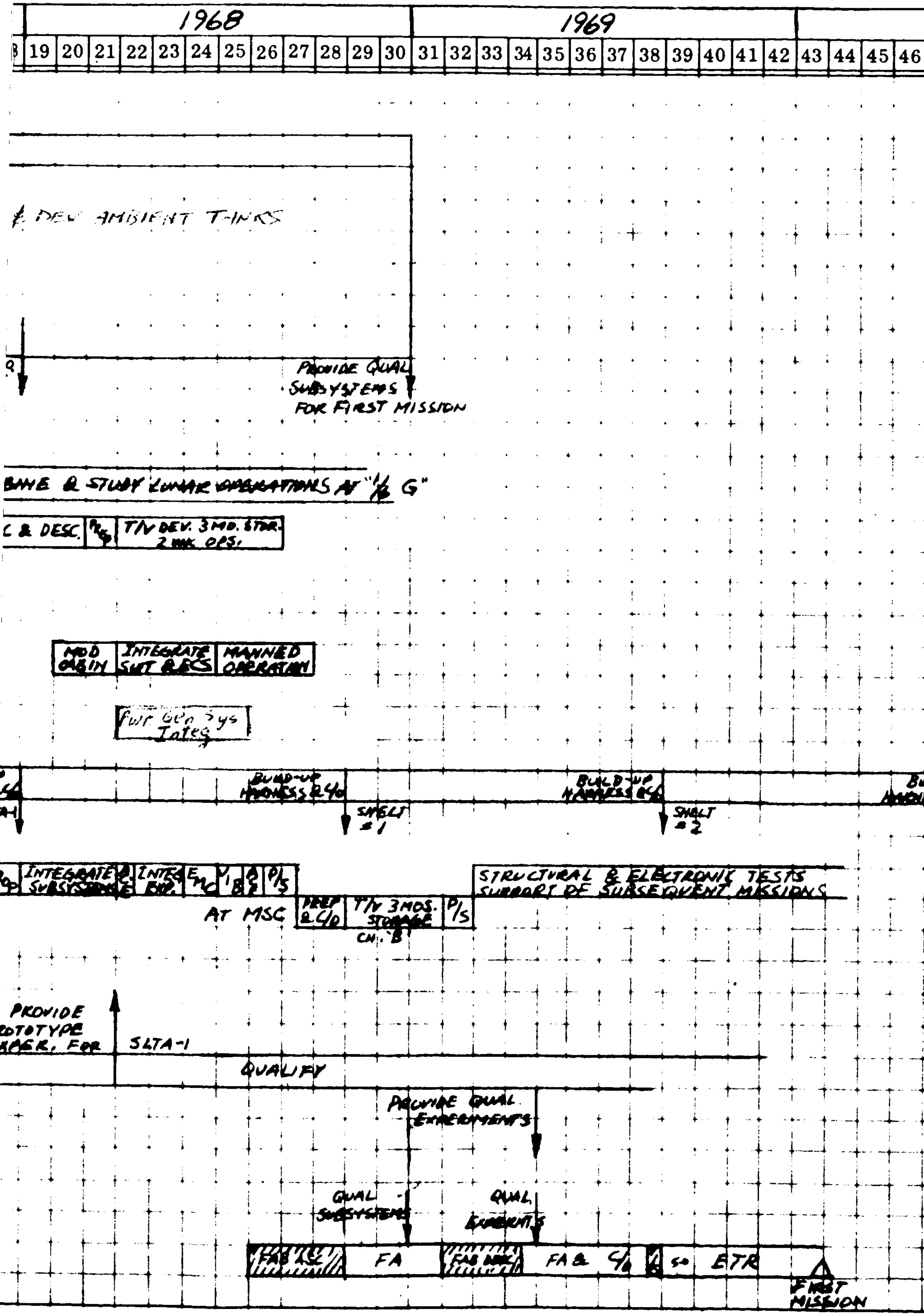

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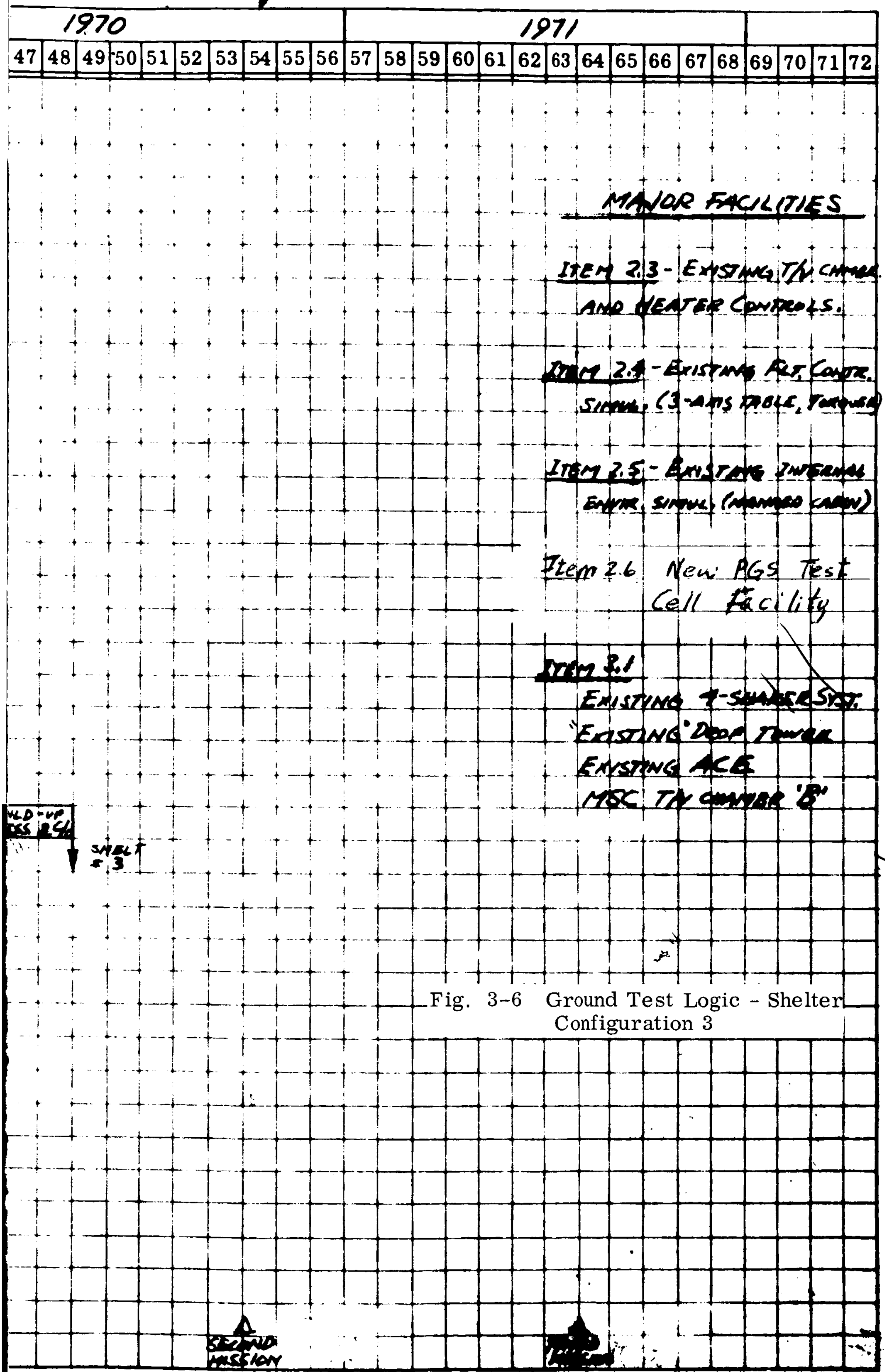

Fig. 3-6 Ground Test Logic - Shelter Configuration 3

[redacted]

3

	1966 (months 1–6)	1967 (months 7–18)
GO-AHEAD	▲ (month 1)	
1.0 SUBSYSTEMS DEVEL.		
1.1 S&C		
1.2 G&N		
1.3 CREW PROV		
1.4 ECS	MOD. FOR IMU, ASA	
1.5 INSTR	MOD	
1.6 EPS	MOD	
1.7 PROP.	MOD	
1.8 RCS		
1.9 COMM	MOD	
1.10 C&D		
	PROVIDE PROTO LDG. BEACON & RR SYST FOR FCI	PROVIDE DATA FOR BATT. MASS & THERM SIMULATORS
2.0 COMBINED SUBSYSTEMS		
2.1 TTM-1 THERMAL MODEL	TM-2 A/D FROM LEM; DES. BATT.	MOD. TM-2 DESC. / MODIFY TM-2 ASC. / PREP / T/V DEV. — LAB RE…
2.2 STRUCT. ELEM. BATT. BAY	INSTAL.	FAB / INST / WB / STAT
2.3 FCI FLT CONTR SIMUL.	FCI FOR BEACON LDG	SHELF REL
2.4 ESI HARNESS FAB & C/O		
3.0 SYSTEM VERIFIC.		
3.1 TLTA-1 LTA-8 FROM LEM		
4.0 MISSION - TAXI 2		

SUBSYSTEMS LIFE EXTENSION TESTS FOR ASCENT & REND. AFTER 2 WKS. QUIESCENT STORAGE

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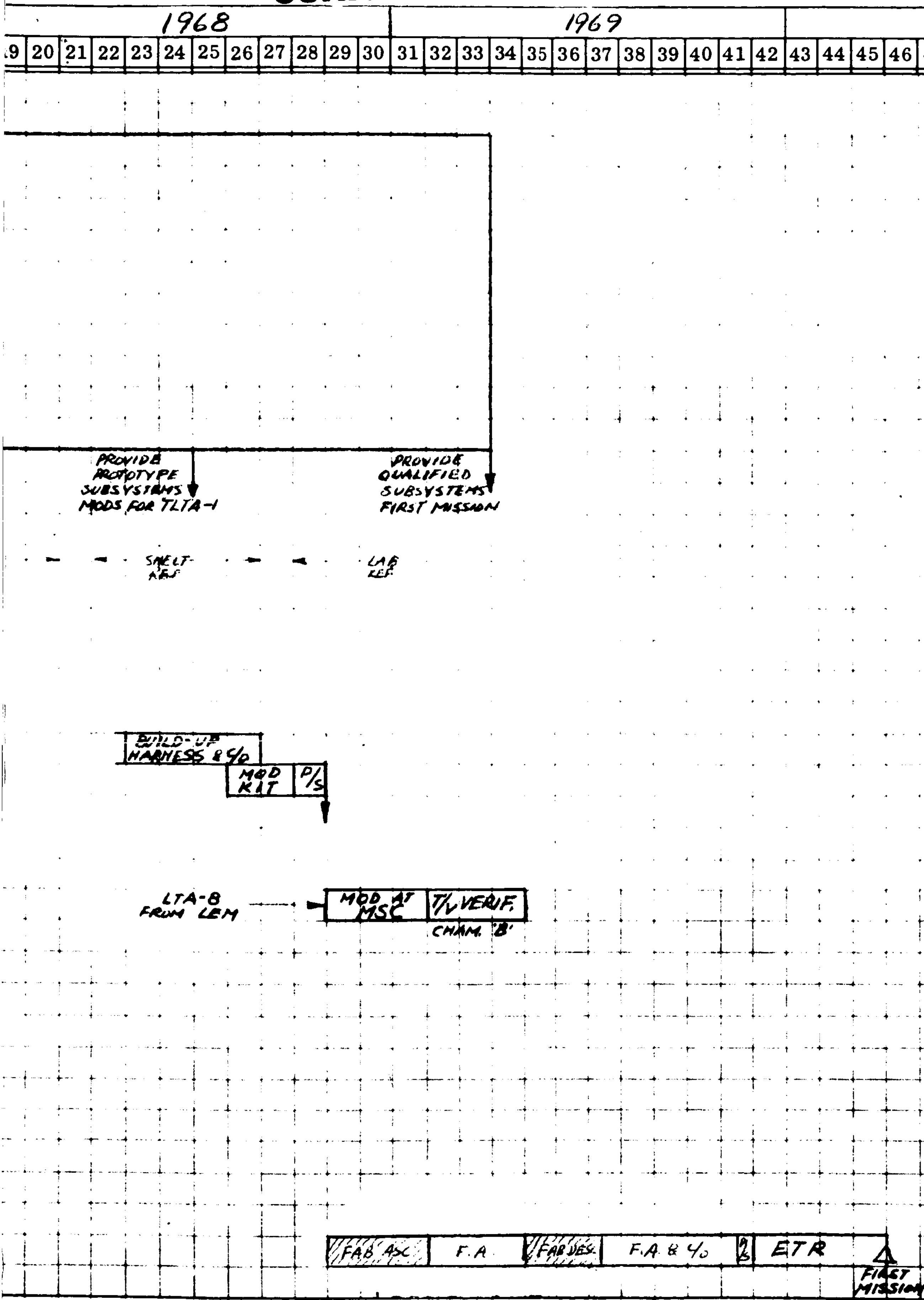

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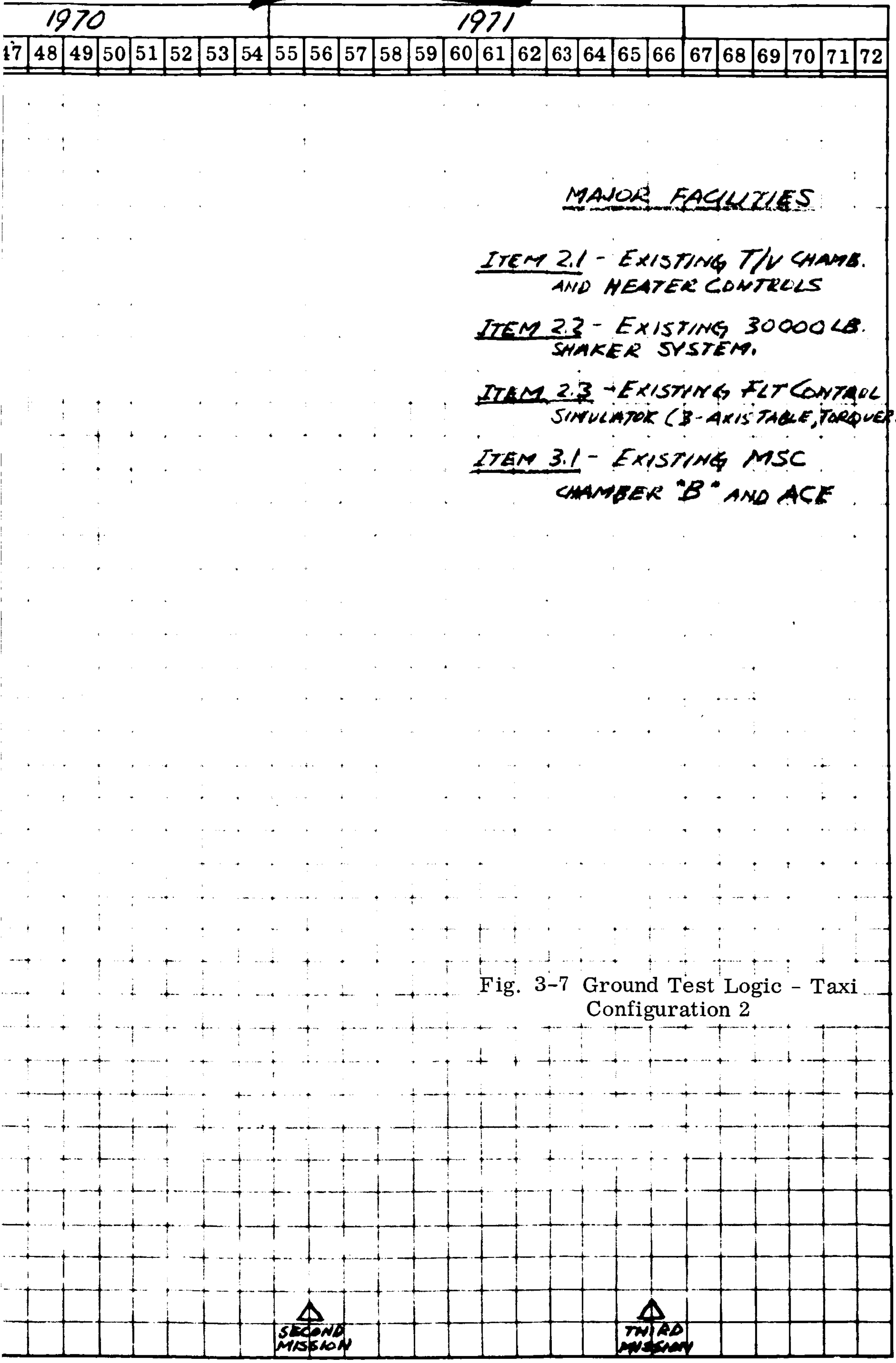

Fig. 3-7 Ground Test Logic - Taxi Configuration 2

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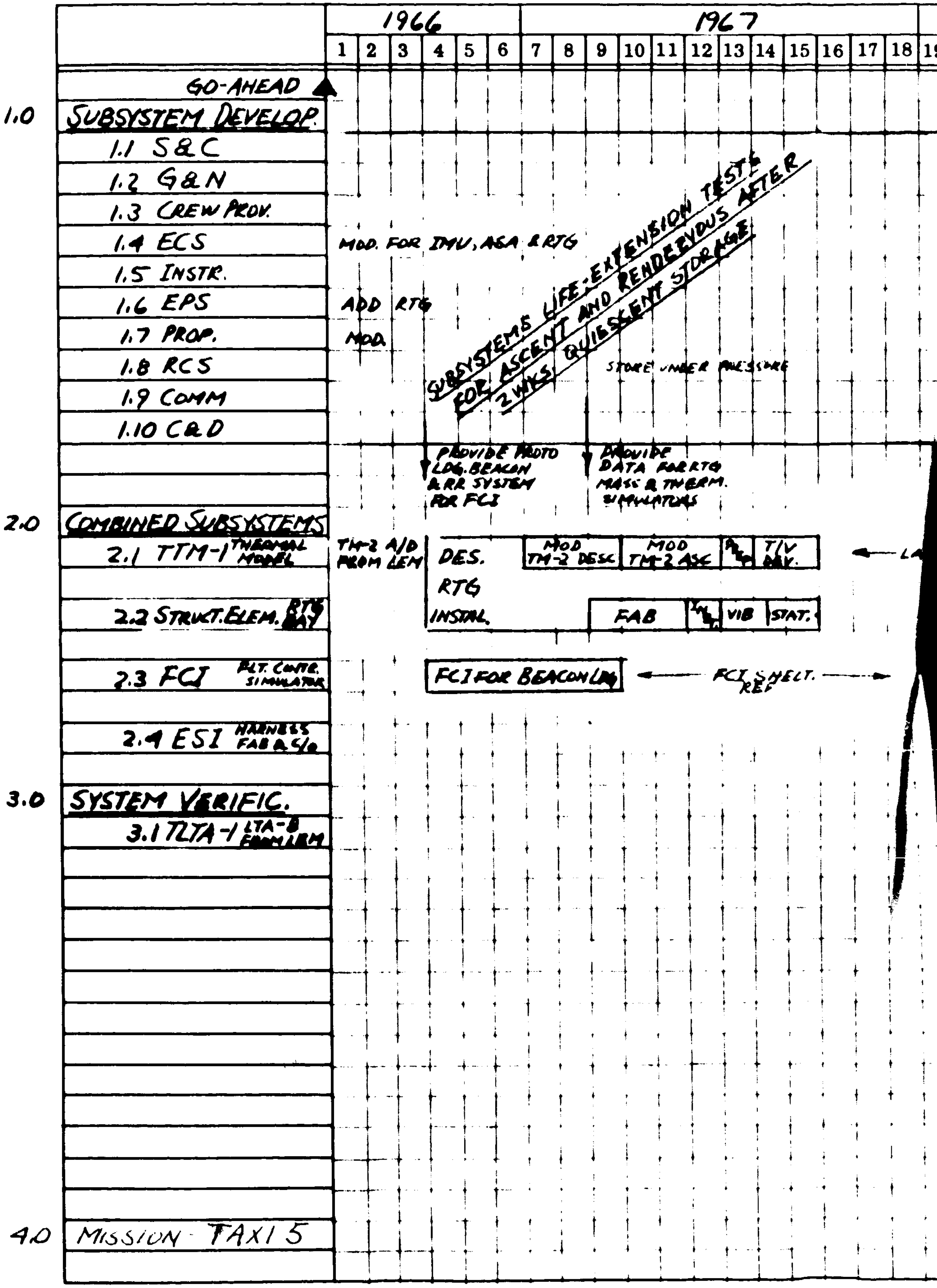

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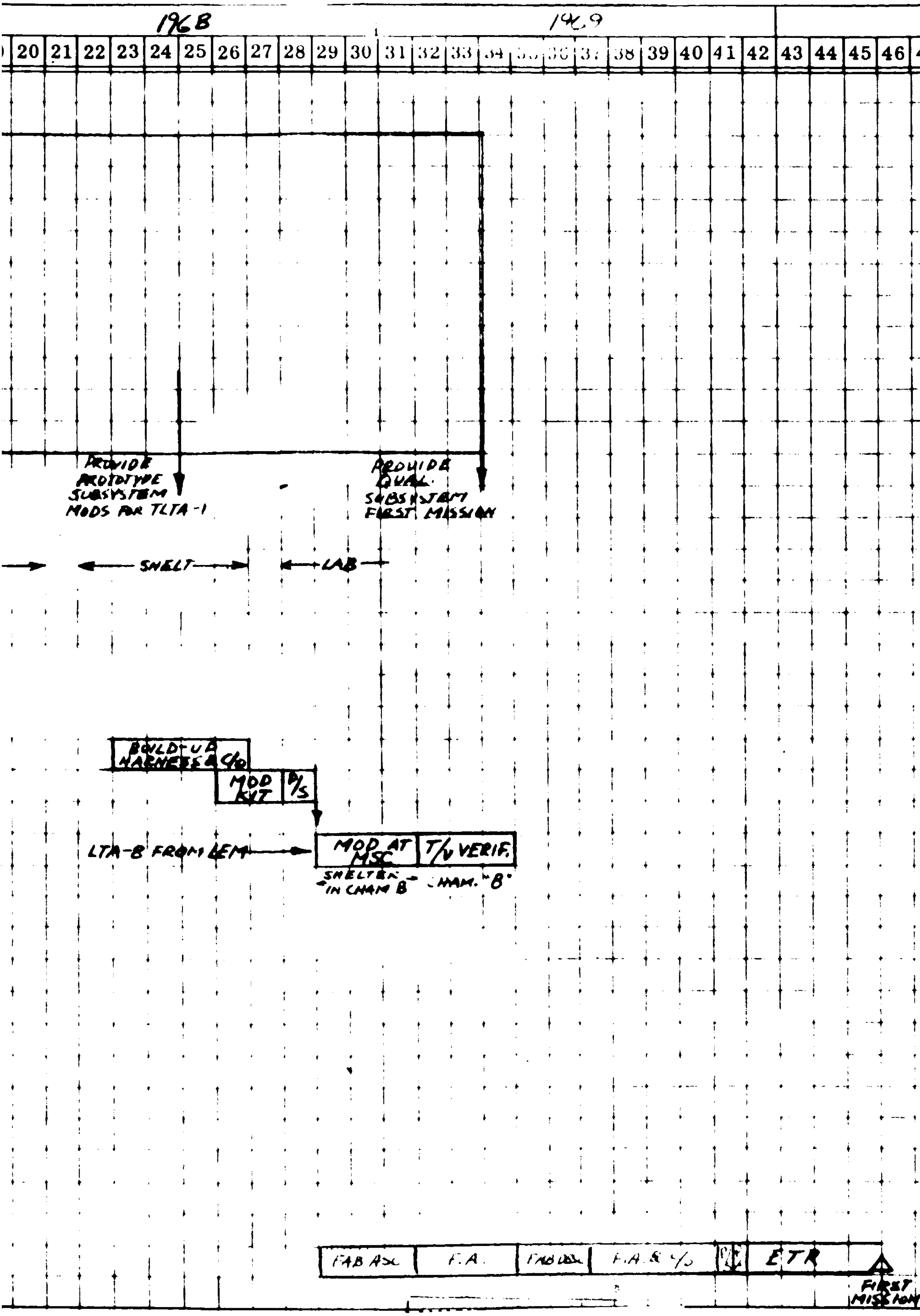

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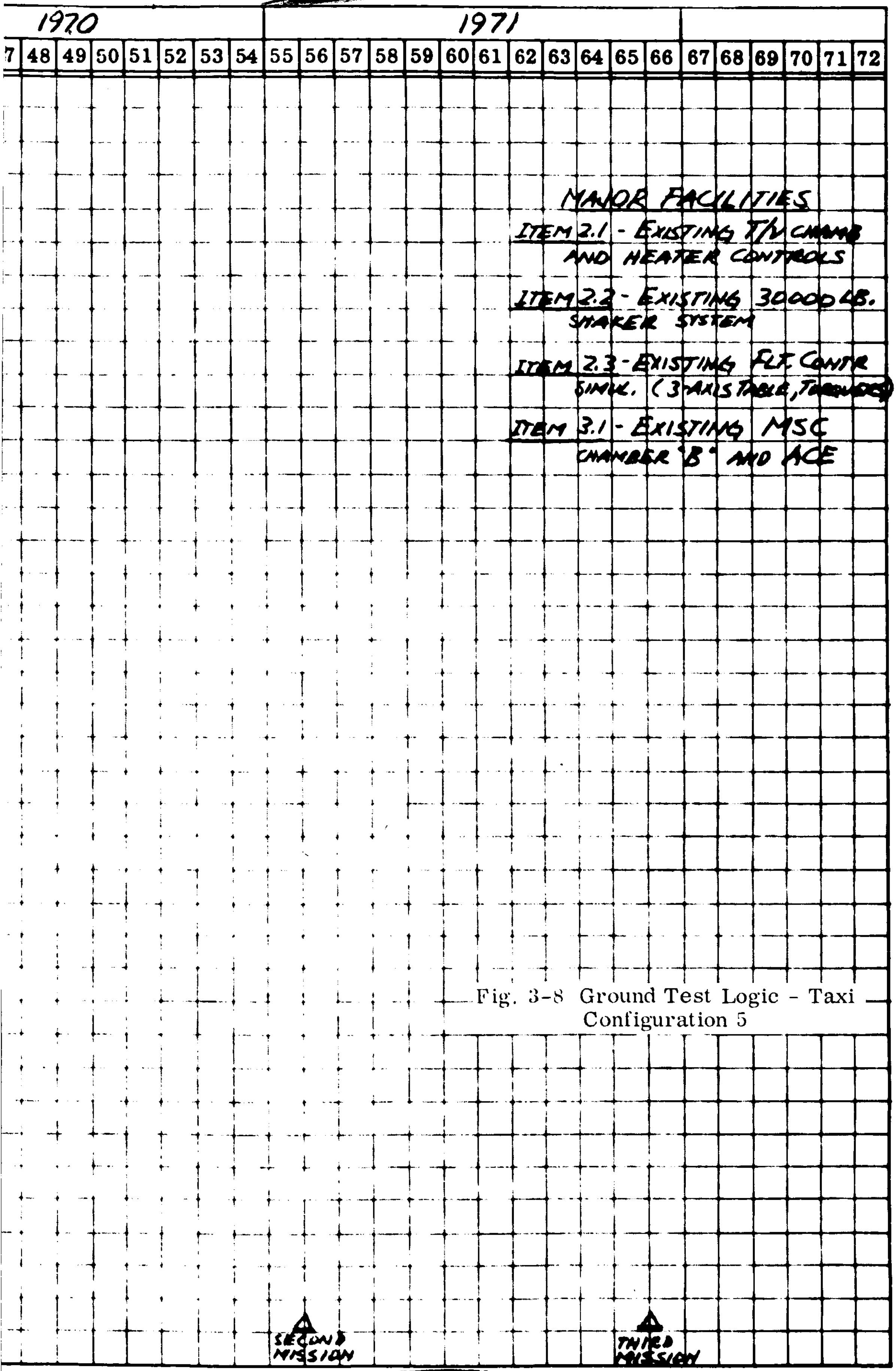

Fig. 3-8 Ground Test Logic - Taxi Configuration 5

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3

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		1966						1967											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.0	SUBSYSTEM DEVELOP.																		
	1.1 STRUCT.	ADD RCS AND ALL SUBSYSTEMS TO DESCENT STAGE (W/ L.G.) DELETE ASCANT STAGE ADD PAYLOAD SUPP'T STRUCT.																	
	1.2 S&C																		
	1.3 G&N	UNMANNED LDG.																	
	1.4 ECS																		
	1.5 INSTR.																		
	1.6 EPS																		
	1.7 PROP. DESC ONLY																		
	1.8 RCS IN DESC.																		
	1.9 COMM.																		
2.0	COMBINED SUBSYSTEMS																		
	2.1 INT. MOCK-UP																		
	2.2 EXT. MOCK-UP PAYLOAD INTERFACE																		
	2.3 TM THERMAL MODEL																		
	2.4 TM VIBR & DROP MODEL																		
	2.5 FCI FLT CONTR. SIMUL.																		
	2.6 RCS-RIG RCS HOT FIRING																		
	2.7 ESI HARNESS FAB & C/O																		
3.0	SYSTEM VERIFICATION																		
	3.1 TTA-1 (ELECTRONIC (NON-STRUCT)																		
	3.2 TTA-2 STRUCT/ ENVIRON.																		
4.0	PAYLOAD																		
5.0	MISSION - TRUCK																		

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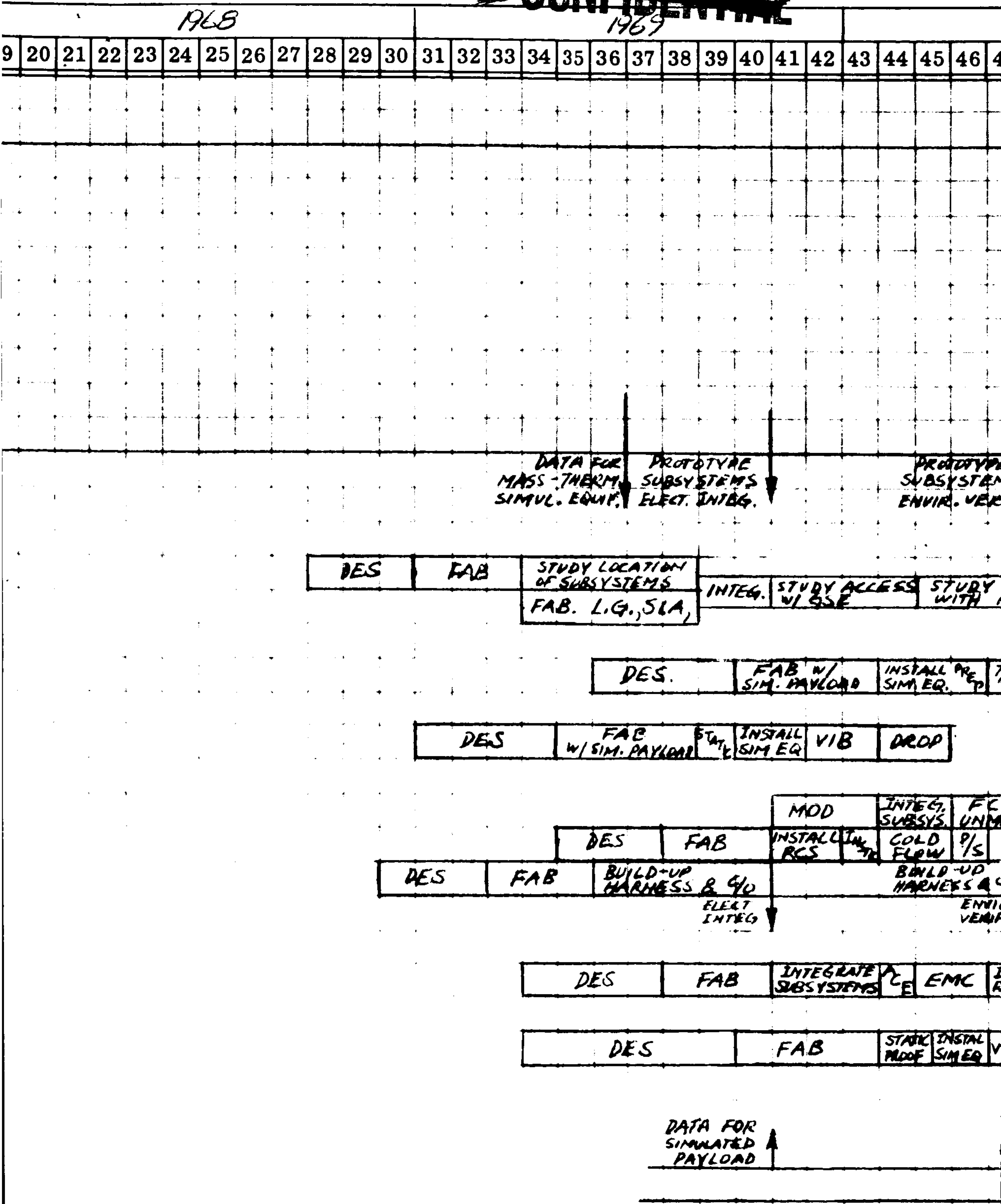

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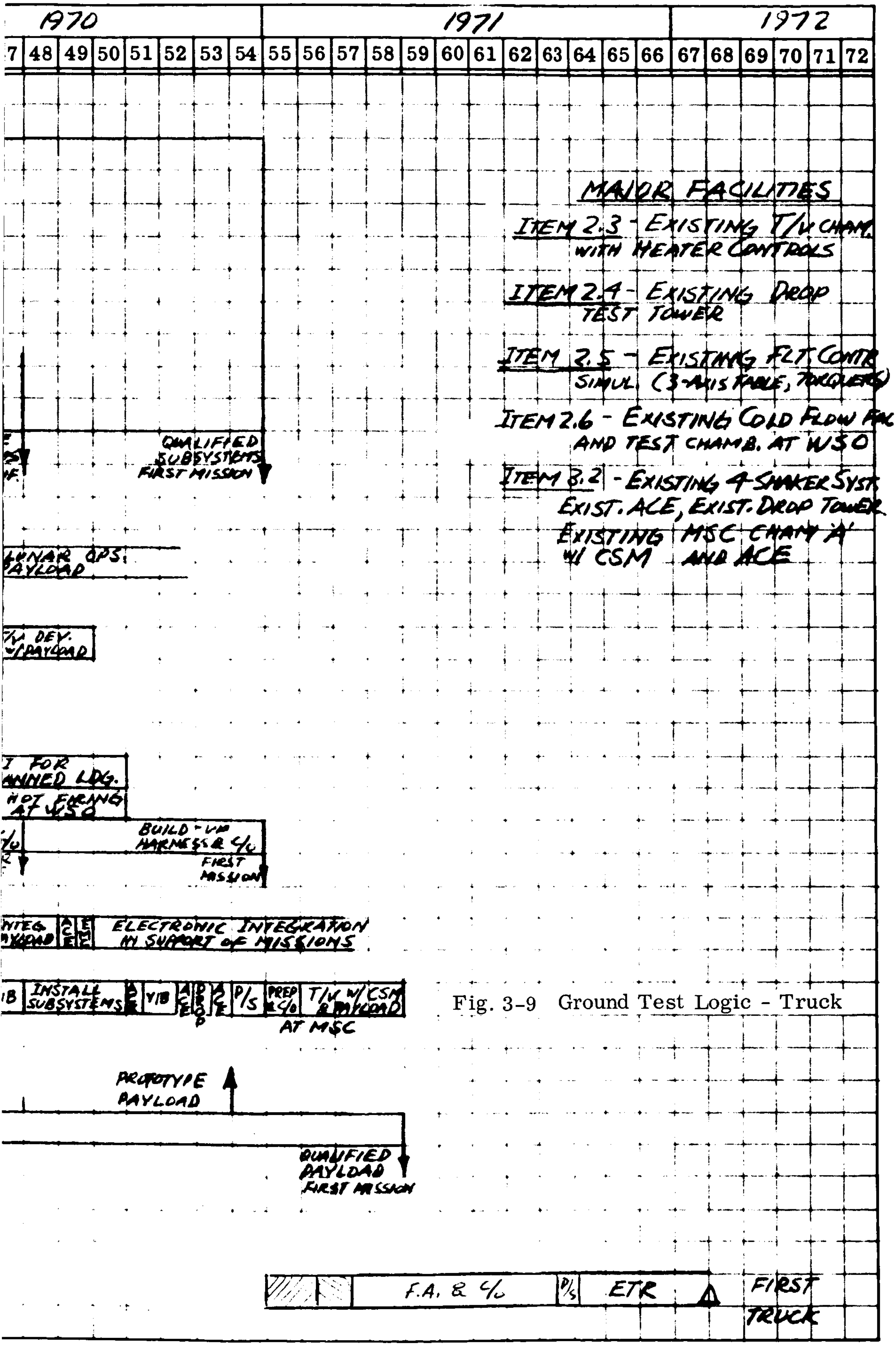

Fig. 3-9 Ground Test Logic - Truck

TABLE 3.3-1

L.O. LAB CONFIG. 1 GROUND TEST ARTICLES & FACILITIES

Item	Description	Purpose
Mock-Up Exterior Interior LM-1 Exterior LM-2 Interior LM-3 Combined (With CSM)	Structure - Full scale, wood and metal. Ascent and Descent stages (without landing gear). Portions of SLA and CSM as required. Interior and exterior built separately for parallel study efforts, then combined. Subsystems - Full scale mock-up, wood and metal. Experiment Payload - Full scale mock-up, wood and metal Major Facilities - None Note: Includes fluid lines mock-up only (Electrical lines on ESI Rig)	• Determine subsystem location particularly for ECS Radiator and EPS fuel cells and cryo tanks • Determine experiment locations and Controls and Displays for Exper. • Determine handling and transport requirements • Demonstrate SLA and GSE accessibility and service • Demonstrate experiment operation with suited crew.
Test Model (Thermal) LTM-1	Structure - Full scale thermal model of Asc. & Descent stages with a CSM thermal simulator. Cabin shall sustain operating pressure without leakage. Other structure will not be loaded and does not require structural integrity. Electrical heaters will be installed on thermal shields. Subsystems - Operating ECS Heat Transport Section with Cabin Pressurization and Temp. Controls as necessary. Other subsystem equip. lines, tanks, and expendables are thermally simulated. Experiment Payload - Thermal model or simulation Major Facilities - T/V chamber with Heater Controls and Data Acquisition.	• Evaluate passive and active thermal control for translunar and lunar orbit phases. • Optimize subsystem location, support and insulation • Optimize heat transport operation with radiator and water boiler • Optimize experiment location, support and insulation for various configurations. • Verify thermal analysis

TABLE 3.3-1 (cont)

Item	Description	Purpose
Internal Environment Simulator IES-L	Structure - None required Subsystems - ECS atmosphere revitalization and suit loop. Water management, waste disposal as necessary. Instrum. and Controls & Displays as required for ECS. Interior of cabin mocked-up. Experiment Payload - Experiments in cabin shall be simulated. Major Facilities - The LEM Internal Environment Simulator modified as required, with associated controls, instrumentation and biomedical services.	• Integration and manned operation of the ECS, Suit, and experiments within the cabin under correct pressure and oxygen conditions. • Biomedical studies for extended missions with man and experiments. • Baseline data acquisition for the man/experiment in the simulated environment.
Power Generation Simulator PGS-L	Structure - Thermal model of structure supporting and surrounding Fuel Cell Power Generation Section. Subsystems - ECS, EPS, and Instrum. req'd for operation and temp. control of PGS. Experiment Payload - Dummy electrical loads Major Facilities - T/V chamber with Heater Controls & Data Acquisition. Suitable for cryogenic hydrogen and oxygen fuel cell reactants.	• Integration of the EPS subassemblies • Evaluation of fuel cell operation when integrated with the ECS and Structure in a simulated L.O. thermal-vacuum environment. • Evaluate thermal effects of operation on surrounding structure and equipment in conjunction with LTM-1 test.

TABLE 3.3-1 (cont)

Item	Description	Purpose
Electr. Harness Integration and Checkout Rig ESI-L	Structure - Full scale metal skeleton, Asc/Desc, having correct geometry and interfaces for electrical and structural attachments for cable fabrication and C/O. Subsystems - Represented by electrical interfaces only such as splices, plugs, connectors, or panels. Experiment Payload - Represented by electrical interfaces only. Major Facilities - Minor Automatic Circuit Checkout System. (DITMICO)	• Fabricate electrical and electronic harnesses and cables for the unique Lab and experiment configurations. • Checkout cables during fabrication and build-up. • Preparation of photographic lines installation drawings.
System Verific. Test Article (Electronic) LLTA-1	Structure - Complete Asc/Desc. structure. No pressurization or leakage requirements for cabin. No requirement for structural integrity, no thermal insulation or thermal shielding req'd, no landing gear. Subsystems - All subsystems will be functionally complete with ECS and GSE cooling and of at least a prototype level. Experiment Payload - Same as subsystems Major Facilities - ACE (EMI Screen Room and Test Equip. also req'd)	• Electronic integration and functional testing of all subsystem and experiment configurations and combined with ACE and GSE. • Electromagnetic interference evaluation and control of operating subsystems and experiments with ACE and GSE functions. • Demonstration of electronic compatibility of subsystems, experiments, ACE and GSE.

TABLE 3.3-1 (cont)

Item	Description	Purpose
System Verific. Test Article (Environmental) LLTA-2	Structure - Complete Asc/Desc. stages structurally and thermally representative. Modifications must maintain structural and thermal integrity. Cabin leakage critical. Subsystems - All subsystems will be functionally, structurally, and thermally complete and of at least a prototype level. Expendables will be mass and thermally simulated where they cannot be present. The Life Support Section of ECS will be reconditioned for manned T/V operations. Note: Mass simulators will replace limited-life equipment for modal vibration studies. Experiment Payload - Same as subsystems. Major Facilities - 4-shaker vibration system with data acquisition for Modal Survey and later verification of equipment with ACE and GSE. (Minor static test equipment also req'd.) Thermal-Vacuum Chamber "A" at MSC with ACE and GSE. (With CSM.) Note: Chamber "A" at MSC may require modifications for Lunar Orbital Radiation and Albedo Thermal Simulation.	• Verify the structural integrity of critical Lab configurations under static proof loads. • Evaluate vibration modes and levels of critical configurations using simulated equipment. • Verify subsystem and experiment operation under mission level vibrations. • Verify manned operation in a thermal-vacuum environment simulating translunar and lunar orbit mission phases as combined with the Command Module. • Verify weight, c.g., and moments-of-inertia for all configurations.

TABLE 3.3-2

L.O. LAB CONFIG. 2 GROUND TEST ARTICLES & FACILITIES

Item	Description	Purpose
Mock-Up Exterior and Interior LM-1 Exterior LM-2 Interior LM-3 Combined (with CSM)	Structure - Full scale, wood and metal. Ascent and low prof. des. stages (without landing gear). Portions of SLA and CSM as required. Interior and exterior built separately for parallel study efforts, then combined. Subsystems - Full scale mock-up, wood & met. Experiment Payload - Full scale mock-up, wood & met. Major Facilities - None Note: Includes fluid lines mock-up only (Electrical lines on ESI Rig)	• Determine subsystem location particularly for ECS Radiator and EPS fuel cells and cryo tanks. • Determine experiment locations and controls & displays for exper. • Determine handling & transport requirements with new low profile descent stage • Demonstrate SLA and GSE accessibility & service • Demonstrate experiment operation with suited crew
Test Model (Thermal) LTM-1	Structure - Full scale thermal model of asc. stage & low profile desc with a CSM thermal simulator. Cabin shall sustain operating pressure without leakage, other structure will not be loaded and does not require structural integrity. Electrical heaters will be installed on thermal shields. Subsystems - Operating ECS heat transport section with cabin pressurization and temp. controls as necessary. Other subsystem equip. lines, tanks, and expendables are thermally simulated. Experiment Payload - Thermal model or simulation Major Facilities - T/V chamber with heater controls and data acquisition.	• Evaluate passive and active thermal control for translunar and lunar orbit phases. • Optimize subsystem location, support and insulation • Optimize heat transport operation with radiators and water boiler. • Optimize experiment location, support and insulation for various configurations. • Verify thermal analysis

TABLE 3.3-2 (cont)

Item	Description	Purpose
Internal Environment Simulator IES-L	Structure - None required Subsystems - ECS atmosphere revitalization and suit loop. Water management, waste disposal as necessary. Instrum. and controls & displays as required for ECS. Interior of cabin mocked-up. Experiment Payload - Experiments in cabin shall be simulated. Major Facilities - The LEM internal environment simulator modified as required, with associated controls, instrum. and biomedical services.	• Integration and manned operation of the ECS, suit, and experiments within the cabin under correct pressure and oxygen conditions. • Biomedical studies for extended missions with man and experiments. • Base line data acquisition for the man/experiment in the simulated environment.
Power Generation Simulator PGS-L	Structure - Thermal model of structure supporting and surrounding fuel cell power generation section. Subsystems - ECS, EPS, and instrum. required for operation and temp. control of PGS. Experiment Payload - Dummy electrical loads Major Facilities - T/V chamber with heater controls and data acquisition. Suitable for cryogenic hydrogen and oxygen fuel cell reactants.	• Integration of EPS subassemblies • Evaluation of fuel cell operation when integrated with the ECS and structure in a simulated L.O. thermal-vacuum environment. • Evaluate thermal effects of operation on surrounding structure and equipment in conjunction with LTM-1 test.

TABLE 3.3-2 (cont)

Item	Description	Purpose
Electr. Harness Integration & Checkout Rig ESI-L	Structure - Full scale metal skeleton, ASC/LPDS, having correct geometry and interfaces for electrical and structural attachments for cable fabrication and c/o. Subsystems - Represented by electrical interfaces only, such as splices, plugs, connectors, or panels. Experiment Payload - Represented by electrical interfaces only. Major Facilities - Automatic circuit checkout system (DITMCO)	• Fabricate electrical and electronic harnesses and cables for the unique Lab and experiment configurations. • Checkout cables during fabrication and build-up. • Preparation of photographic lines installation drawings.
System Verific. Test Article (Electronic) LLTA-1	Structure - Complete ASC/LPDS structure. No pressurization or leakage requirements for cabin, no requirement for structural integrity, no thermal insulation or thermal shielding required, no landing gear. Subsystems - All subsystems will be functionally complete with ECS and GSE cooling and of at least a prototype level. Experiment Payload - Same as subsystems Major Facilities - ACE (EMI screen room & test equip. also required)	• Electronic integration and functional testing of all subsystem and experiment configurations with the new low profile descent stage and combined with ACE and GSE. • Electromagnetic interference evaluation and control of operating subsystems and experiments with ACE and GSE functions • Demonstration of electronic compatibility of subsystems, experiments, ACE and GSE

TABLE 3.3-2 (cont)

Item	Description	Purpose
<u>System Verific. Test Article</u> (Environmental) <u>LLTA-2</u>	<u>Structure</u> - Complete Asc/LPD stages structurally and thermally representative. Modifications must maintain structural and thermal integrity. Cabin leakage critical. <u>Subsystems</u> - All subsystems will be functionally, structurally and thermally complete and of at least a prototype level. Expendables will be mass and thermally simulated where they cannot be present. The Life Support Section of ECS will be reconditioned for T/V operations. Note: Mass simulators will replace limited-life equipment for modal vibration studies. <u>Experiment Payload</u> - Same as subsystems <u>Major Facilities</u> - 4-shaker vibration system with data acquisition for modal survey and later verification of equipment with ACE & GSE. (Minor static test equipment also required) Thermal-vacuum chamber "A" at MSC with ACE and GSE (with CSM) Note: Chamber "A" of MSC may require modifications for Lunar Orbital Radiation and Albedo Thermal Simulation.	• Verify the structural integrity of the low profile descent stage and of critical Lab configurations under static proof loads. • Evaluate vibration modes and levels of critical configurations using simulated equipment. • Verify subsystem and experiment operation under mission level vibrations. • Verify manned operation in a thermal vacuum environment simulating translunar and lunar orbit mission phases as combined with the Command Module. • Verify weight, c.g., and moments-of-inertia for all configurations.

TABLE 3.3-3

SHELTER CONFIG. 1 GROUND TEST ARTICLES & FACILITIES

Item	Description	Purpose
Mock-Up Exterior and Interior SM-1 Ext. SM-2 Int. SM-3 Combined	Structure - Full scale, wood and metal. Asc. and desc. stages with landing gear. Portions of SLA as required. Interior and exterior built separately for parallel study efforts then combined. Subsystems - Full scale, wood and metal. Include fluid lines only (elect. lines on ESI rig.) Experiment Payload - Full scale, wood & metal Major Facilities - None	• Determine subsystem locations with added GOX and H_2O tanks. • Study sleeping and experiment arrangements and hygienic provis. • Determine experimental payload locations and controls & displays • Determine handling and transportation arrangements. • Demonstrate SLA and GSE accessibility & service. • Demonstrate experiment operation and deployment with suited crew at "1/6 g"
Test Model (Thermal) STM-1	Structure - Full scale thermal model of Asc. & desc. stages with CSM thermal simulator and without landing gear or adapter truss. This is the LEM TM-2 modified to the Shelter configuration from the Taxi configuration. Electrical heaters will be installed on thermal shields. Subsystems - Operating open cycle ECS with H_2O boiler; cabin pressurization and temp. controls required. Other subsystem equipment and lines & tanks are thermally simulated. Experimental Payload - Thermal model or simulator Major Facilities - T/V chamber with heat controls and data acquisition.	• Evaluate passive and active thermal control for translunar or lunar mission phases. • Optimize subsystem location, support and insulation. • Optimize heat transport operation of cold plates and water boiler. • Optimize experimental location, support and insulation for the various unique configurations.

TABLE 3.3-3 (cont)

Item	Description	Purpose
Flight Control Simulator FCI-S	Structure - None Subsystems - G & N, S & C, and Controls and Displays subsystems of at least a prototype level. Computer programs appropriate to flight simulation of unmanned lunar landings shall be provided. Experiment Payload - Mass and inertia parameters shall be provided Major Facilities - 3-axis table, torquers for sensors, data acquisition, computers.	• Evaluate and optimize various unmanned lunar landing trajectories. • Evaluate and optimize the lunar landing programs for various experimental payload configurations • Verify selected programs with final parameters prior to launch.
Internal Environment Simulator IES-S	Structure - None Subsystems - ECS atmosphere revitalization for cabin and suit loop. Sleeping facilities, water management, waste disposal and hygiene provisions as required. Instrum. and controls & displ. as necessary for operation of ECS and experiments. Interior of cabin mocked-up. Experiment Payload - Experiments in cabin shall be simulated. Major Facilities - The LEM internal environment simulator modified as necessary with associated controls, instrument, and biomedical services.	• Integration and manned verification of the operation of the suit, ECS, and crew provisions within the cabin under correct pressure and oxygen conditions. • Biomedical studies for extended lunar stay.

TABLE 3.3-3 (cont)

Item	Description	Purpose
Electr. Harness Integration & Checkout Rig ESI-S	Structure - Full scale metal skeleton, Asc. & desc., without landing gear or adapter truss. Has correct geometry and interfaces for all electrical and structural attachments for cable fabrication and checkout. Subsystems - Represented by electrical interfaces only such as splices, plugs, connectors, buss bars, or panels. Experiment Payload - Elect. interfaces only Major Facilities - Minor automatic circuit checkout system (DITMCO)	• Fabricate electrical and electronic harnesses and cables for each Shelter and exper. configuration. • Checkout cables during fabrication and build-up. • Prepare Photographic lines installation drawings.
System Verification Test Article Electronic and environmental SLTA-1	Structure - Complete asc. & desc. stages with landing gear, structurally and thermally representative of each config. Modifications must maintain structural, thermal, and cabin leakage integrity. Subsystems - Limited-life equipment will be replaced by mass simulators for the modal vibration and landing impact surveys. Expendables will be mass or thermally simulated where they cannot be present. For the system verification test the subsystems will be functionally, structurally, and thermally complete prototypes, representative of qualified equipment. The cabin and ECS life support section will be reconditioned as necessary for manned T/V operations at MSC. Experiment Payload - Same as subsystems. Major Facilities - 4-shaker vibration system with data acquisition for Modal Survey and for system verification with ACE and GSE. Drop test towers and data acquisition Thermal-vacuum cham. "B" at MSC w/ACE, GSE. Note: Chamber "B" may require modifications for lunar storage radiation & albedo simulation.	• Verify the structural integrity of unique Shelter configurations under static proof loads. • Evaluate vibration modes and levels for unique configurations using mass simulated equipment. • Evaluate landing stability and energy absorption characteristics for envelope mass, c.g., and inertia parameters. • Verify subsystems and experiment operation under mission level vibrations. • Verify electromagnetic interference control. • Verify weight, c.g. and inertias for all unique configurations. • Verify manned operations in MSC chamber "B" following the trans-lunar and lunar storage phases.

TABLE 3.3-4

SHELTER CONFIG. 2 GROUND TEST ARTICLES & FACILITIES

Item	Description	Purpose
Mock-Up Exterior and Interior SM-1 Ext. SM-2 Int. SM-3 Combined	Structure - Full scale, wood and metal. Asc. and desc. stages with landing gear. Portions of SLA as required. Interior and exterior built separately for parallel study efforts, then integrated. Subsystems - Full scale, wood and metal. Include fluid lines only (electr. lines on ESL rig.) Experimental Payload - Full scale, wood & metal Major Facilities - None	• Determine subystem locations with early effort for ECS radiator and EPS fuel cells and Cryo tankage. • Determine experiment payload locations and controls & displays. • Determine handling and transportation arrangements. • Demonstrate SLA and GSE accessibility & service. • Demonstrate Experiment operation and deployment with suited crew at 1/6 g.
Test Model (Thermal) STM-1	Structure - Full scale thermal model of Asc. & desc. stages with CSM thermal simulator and without landing gear or adapter. This is the LEM TM-2 modified to the Shelter config. from the Taxi config. Electrical heaters will be installed on thermal shields. Subsystems - Operating closed cycle ECS with radiator, cabin pressurization and temp. controls required. Other subsystem equipment and lines & tanks are thermally simulated. Experimental Payload - Thermal model or simulation. Major Facilities - T/V chamber with heater controls and data acquisition.	• Evaluate passive and active thermal control for translunar and lunar storage and operation phases. • Optimize subsystem location, support and insulation. • Optimize heat transport operation with radiator and water boiler. • Optimize experiment location, support and insulation for the various unique configurations.

TABLE 3.3-4 (cont)

Item	Description	Purpose
Flight Control Simulator FCI-S	Structure - None Subsystems - G & N, S & C, and Controls and displays subsystems of at least a prototype level. Computer programs appropriate to flight simulation of unmanned lunar landing shall be provided. Experiment Payload - Mass and inertia parameters shall be provided. Major Facilities - 3-axis table, torquers for sensors, data acquisition, computers	• Evaluate and optimize various unmanned lunar landing trajectories. • Evaluate and optimize the lunar landing programs for various experimental payload configurations. • Verify selected programs with final parameters prior to launch.
Internal Environment Simulator IES-S	Structure - None Subsystems - ECS atmosphere revitalization for cabin and suit loop. Sleeping facilities, water management, waste disposal and hygienic provisions as required. Instrum. and controls & displ. as necessary for operation of ECS and experiments. Interior of cabin mocked-up. Experiment Payload - Experiments in cabin shall be simulated. Major Facilities - The LEM internal environment simulator modified as necessary with associated controls, instrument, and biomedical services.	• Integration and manned verification of the operation of the suit, ECS and crew provisions within the cabin under correct pressure and oxygen conditions. • Biomedical studies for extended lunar stay.

TABLE 3.3-4 (cont)

Item	Description	Purpose
Power Generation Simulators PGS-S	Structure - Thermal model of structure supporting and surrounding fuel cell power generation section. Subsystems - ECS, EPS, and instrum. necessary for operation and temp. control of PGS. Dummy electrical loads for others. Experiment Payload - Dummy electric loads. Major Facilities - T/V chamber with heater controls and data acquisition. Suitable for cryogenic hydrogen and oxygen fuel cell reactants.	• Evaluation and verification of fuel cell operation when integrated with the ECS and structure in a simulated lunar stay thermal-vacuum environment. • Verify lunar storage and restart capabilities. • Demonstrate cryogenic storage capability. • Evaluate thermal effects of operation and storage on surrounding structure and equipment in conjunction with STM-1 test.
Electr. Harness Integration & Checkout Rig ESI-S	Structure - Full scale metal skeleton, asc. & desc. structure W/O landing gear. Has correct geometry & interfaces for all elect. & struct. attach. for cable fabrication and checkout. Subsystems - Represented by electrical interfaces only such as splices, plugs, connectors, bus bars, or panels. Experiment Payload - Elect. interfaces only Major Facilities - Minor automatic circuit checkout system (DITMCO)	• Fabricate electrical and electronic harnesses and cables for each Shelter and experiment configuration. • Checkout cables during fabrication and build-up. • Prepare photographic lines installation drawings.

TABLE 3.3-4 (cont)

Item	Description	Purpose
System Verification Test Article Electronic & Environmental SLTA-1	Structure - Complete asc. & desc. stages with landing gear, structurally and thermally representative of each configuration. Modifications must maintain structural, thermal, and cabin leakage integrity. Subsystems - Limited-life equipment will be replaced by mass simulators for the modal vibration and landing impact surveys. Expendables will be mass or thermally simulated where they cannot be present. For the system verification tests the subsystems will be functionally, structurally, and thermally complete prototypes, representative of qualified equipment. The cabin and ECS life support section will be reconditioned as necessary for manned T/V operations at MSC. Experiment Payload - Same as subsystems Major Facilities - 4-shaker vibration system with data acquisition for modal survey and for system verification with ACE and GSE. Drop test towers and data acquisition. Thermal-vacuum cham. "B" at MSC w/ACE, GSE. Note: Chamber "B" may require modifications for lunar storage radiation & albedo simulation.	• Integrate fuel cells into EPS and ECS. • Verify the structural integrity of unique Shelter configurations under static proof loads. • Evaluate vibration modes and levels for unique configurations using mass simulated equipment. • Evaluate landing stability and energy absorption characteristics for envelope mass, c.g. and inertia parameters. • Verify electromagnetic interference control. • Verify weight, c.g. and inertias for all unique configurations. • Verify passive and active thermal control for the translunar and lunar storage and operation phases of the mission. • Verify manned operation in MSC chamber "B" following the translunar and lunar storage unmanned phases.

TABLE 3.3-5

SHELTER CONFIG. 3 GROUND TEST ARTICLES & FACILITIES

Item	Description	Purpose
Mock-Up Exterior and Interior SM-1 Ext. SM-2 Int. SM-3 Combined	Structure - Full scale, wood and metal. Asc. and desc. stages with landing gear. Portions of SLA as required. Interior and exterior built separately for parallel study efforts, then integrated. Subsystems - Full scale, wood and metal. Include fluid lines only (electr. lines on ESL rig.) Experimental Payload - Full scale, wood & metal Major Facilities - None	• Determine subystem locations with early effort for ECS radiator and EPS fuel cells and Cryo tankage. • Determine experiment payload locations and controls & displays. • Determine handling and transportation arrangements. • Demonstrate SLA and GSE accessibility & service. • Demonstrate Experiment operation and deployment with suited crew at 1/6 g.
Test Model (Thermal) STM-1	Structure - Full scale thermal model of Asc. & desc. stages with CSM thermal simulator and without landing gear or adapter. This is the LEM TM-2 modified to the Shelter config. from the Taxi config. Electrical heaters will be installed on thermal shields. Subsystems - Operating closed cycle ECS with radiator, cabin pressurization and temp. controls required. Other subsystem equipment and lines & tanks are thermally simulated. Experimental Payload - Thermal model or simulation. Major Facilities - T/V chamber with heater controls and data acquisition.	• Evaluate passive and active thermal control for translunar and lunar storage and operation phases. • Optimize subsystem location, support and insulation. • Optimize heat transport operation with radiator and water boiler. • Optimize experiment location, support and insulation for the various unique configurations.

TABLE 3.3-5 (cont)

Item	Description	Purpose
Flight Control Simulator FCI-S	Structure - None Subsystems - G & N, S & C, and Controls and displays subsystems of at least a prototype level. Computer programs appropriate to flight simulation of unmanned lunar landing shall be provided. Experiment Payload - Mass and inertia parameters shall be provided. Major Facilities - 3-axis table, torquers for sensors, data acquisition, computers	• Evaluate and optimize various unmanned lunar landing trajectories. • Evaluate and optimize the lunar landing programs for various experimental payload configurations. • Verify selected programs with final parameters prior to launch.
Internal Environment Simulator IES-S	Structure - None Subsystems - ECS atmosphere revitalization for cabin and suit loop. Sleeping facilities, water management, waste disposal and hygienic provisions as required. Instrum. and controls & displ. as necessary for operation of ECS and experiments. Interior of cabin mocked-up. Experiment Payload - Experiments in cabin shall be simulated. Major Facilities - The LEM internal environment simulator modified as necessary with associated controls, instrument, and biomedical services.	• Integration and manned verification of the operation of the suit, ECS and crew provisions within the cabin under correct pressure and oxygen conditions. • Biomedical studies for extended lunar stay.

TABLE 3.3-5 (cont)

Item	Description	Purpose
Power Generation Simulators PGS-S	Structure - Thermal model of structure supporting and surrounding fuel cell power generation section. Subsystems - ECS, EPS, and instrum. necessary for operation and temp. control of PGS. Dummy electrical loads for others. Experiment Payload - Dummy electric loads. Major Facilities - T/V chamber with heater controls and data acquisition. Suitable for ambient storage of oxygen fuel cell reactants.	• Evaluation and verification of fuel cell operation when integrated with the ECS and structure in a simulated lunar stay thermal-vacuum environment. • Verify lunar storage and restart capabilities. • Demonstrate ambient storage capability. • Evaluate thermal effects of operation and storage on surrounding structure and equipment in conjunction with STM-1 test.
Electr. Harness Integration & Checkout Rig ESI-S	Structure - Full scale metal skeleton, asc. & desc. structure W/O landing gear. Has correct geometry & interfaces for all elect. & struct. attach. for cable fabrication and checkout. Subsystems - Represented by electrical interfaces only such as splices, plugs, connectors, bus bars, or panels. Experiment Payload - Elect. interfaces only Major Facilities - Minor automatic circuit checkout system (DITMCO)	• Fabricate electrical and electronic harnesses and cables for each Shelter and experiment configuration. • Checkout cables during fabrication and build-up. • Prepare photographic lines installation drawings.

TABLE 3.3-5 (cont)

Item	Description	Purpose
System Verification Test Article Electronic & Environmental SLTA-1	Structure - Complete asc. & desc. stages with landing gear, structurally and thermally representative of each configuration. Modifications must maintain structural, thermal, and cabin leakage integrity. Subsystems - Limited-life equipment will be replaced by mass simulators for the modal vibration and landing impact surveys. Expendables will be mass or thermally simulated where they cannot be present. For the system verification tests the subsystems will be functionally, structurally, and thermally complete prototypes, representative of qualified equipment. The cabin and ECS life support section will be reconditioned as necessary for manned T/V operations at MSC. Experiment Payload - Same as subsystems Major Facilities - 4-shaker vibration system with data acquisition for modal survey and for system verification with ACE and GSE. Drop test towers and data acquisition. Thermal-vacuum cham. "B" at MSC w/ACE, GSE. Note: Chamber "B" may require modifications for lunar storage radiation & albedo simulation.	• Integrate fuel cells into EPS and ECS. • Verify the structural integrity of unique Shelter configurations under static proof loads. • Evaluate vibration modes and levels for unique configurations using mass simulated equipment. • Evaluate landing stability and energy absorption characteristics for envelope mass, c.g. and inertia parameters. • Verify electromagnetic interference control. • Verify weight, c.g. and inertias for all unique configurations. • Verify passive and active thermal control for the translunar and lunar storage and operation phases of the mission. • Verify manned operation in MSC chamber "B" following the translunar and lunar storage unmanned phases.

TAXI CONFIG. 2
GROUND TEST ARTICLES & FACILITIES

TABLE 3.3-6

Item	Description	Purpose
Test Model (Thermal) TTM-1	Structure - Full-scale thermal model of asc. and desc. stages with CSM thermal simulator and without landing gear or adapter truss. This is the LEM TM-2 thermal model modified to the Taxi configuration which will subsequently be modified for use as the Shelter thermal model. Cabin structural and leakage integrity must be maintained. Heaters are installed on thermal shields. Subsystems - Operating open cycle ECS with heat transport section. Cabin pressurization and temp. control required. Other subsystems, lines, tanks, and expendables are thermally simulated. Experiment Payload - None Major Facilities - T/V chamber and heater controls, data acquistion.	• Evaluate passive and active thermal control for ascent after lunar storage with battery EPS. • Optimize subsystem location support and insulation. • Optimize heat transport section distribution. • Evaluate RCS thermal profile after pressurized lunar storage
Test Element (Structural) TTE-1	Structure - Full scale structural element representing the battery installation and local supporting structure. Sufficient structure will be included to obtain the correct interactions for static and vibration tests. Subsystems - Local EPS equipment and lines pertinent to the battery installation will be mass and structurally represented. ECS cold plates will provide correct structural support Experiment payload - None Major Facilities - Minor structural test and vibration equipment.	• Evaluate local structural stresses and deflections of the battery installation for critical static loadings. • Evaluate dynamic response of the battery installation for critical modes of vibration.

TABLE 3.3-6 (cont)

Item	Description	Purpose
Flight Control Simulator FCI-T	Structure - None Subsystem - G & N, S & C and Controls & displays of at least a prototype level for those components needed to simulate lunar landing with beacon combined with rendezvous radar. Experiment Payload - None Major Facilities - 3-axis table, torquers for sensors, data acquisition.	• Evaluate and optimize possible lunar landing trajectories using beacon and rend. radar. • Verify selected programs with final parameters prior to launch.
Electr. Harness Integration & Checkout Rig ESI-T	Structure - Full scale metal skeleton, asc. and desc. stages without landing gear or adapter truss. Has correct geometry and interfaces for all electrical and structural connections for cable fabrication and check-out. Subsystems - Represented by electrical interfaces only, such as splices, plugs, connectors, bus bars, or panels. Experiment Payload - None Major Facilities - Minor automatic circuit checkout system. (DITMCO)	• Fabricate electrical and electronic harnesses and cables for each Taxi. • Checkout cables during fabrication and build-up. • Prepare photographic lines installation drawings.
System Verification Test Article Electronic and Environmental TLTA-1	Structure - Complete asc. and desc. stages with landing gear, structurally and thermally representative of the Taxi. This is the LEM LTA-8 which will be modified as necessary at MSC. Subsystems - Functionally and thermally complete subsystems with the LEM LTA-8, modified and reconditioned as necessary at MSC for manned T/V operations Experiment Payload - None Major Facilities - MSC chamber "B" w/ACE, GSE (some mod's to chamber may be required for lunar storage simulation)	• Verify system operation with ACE after modifications at MSC. • Verify manned operation for ascent and rendezvous after quiescent lunar storage.

TABLE 3.3-7

TAXI CONFIG. 5
GROUND TEST ARTICLES & FACILITIES

Item	Description	Purpose
Test Model (Thermal) TTM-1	Structure - Full scale thermal model of asc. and desc. stages with CSM thermal simulator and without landing gear or adapter truss. This is the LEM TM-2 thermal model modified to the Taxi configuration which will subsequently be modified for use as the Shelter thermal model. Cabin structural and leakage integrity must be maintained. Heaters are installed on thermal shields. Subsystems - Operating open cycle ECS with heat transport section, and simulated radioisotope thermal generator (RTG). Cabin pressurization and temp. control required. Other subsystems, lines, tanks, and expendables are thermally simulated. Experiment Payload - None Major Facilities - T/V chamber and heater controls, data acquisition.	• Evaluate passive and active thermal control for ascent after lunar storage with RTG/Batt. EPS • Optimize subsystem location support and insulation. • Optimize heat transport section distribution • Evaluate RCS thermal profile after pressurized lunar storage.
Test Element (Structural) TTE-1	Structure - Full-scale structural element representing the RTG/Batt. installation and local supporting structure. Sufficient structure will be included to obtain the correct interactions for static and vibration tests. Subsystems - Local EPS equipment and lines pertinent to the RTG/Batt. installation will be mass and structurally represented. ECS cold plates will provide correct structural support. Experiment Payload - None Major Facilities - Minor structural test and vibration equipment.	• Evaluate local structural stresses and deflections of the RTG/Batt. installation for critical static loadings. • Evaluate dynamic response of the RTG/Batt. installation for critical modes of vibration.

TABLE 3.3-7 (cont)

Item	Description	Purpose
Flight Control Simulator FCI-T	Structure - None Subsystems - G & N, S & C and Controls & displays of at least a prototype level for those components needed to simulate lunar landing with beacon combined with rendezvous radar. Software programs as required. Experiment Payload - None Major Facilities - 3-axis table, torquers for sensors, data acquisition, computers.	• Evaluate and optimize possible lunar landing trajectories using beacon and rendezvous radar. • Verify selected programs with final parameters prior to launch.
Electr. Harness Integration & Checkout Rig ESI-T	Structure - Full-scale metal skeleton, asc. and desc. stages without landing gear or adapter truss. Has correct geometry and interfaces for all electrical and structural connections for cable fabrication and checkout. Subsystems - Represented by electrical interfaces only, such as splices, plugs, connectors, bus bars, or panels. Experiment Payload - None Major Facilities - Minor automatic circuit checkout system. (DITMCO)	• Fabricate electrical and electronic harnesses and cables for each Taxi. • Checkout cables during fabrication and build-up. • Prepare photographic lines installation drawings. • Integration of RTG into EPS.
System Verification Test Article Electronic and Environmental TLTA-1	Structure - Complete asc. and desc. stages with landing gear, structurally and thermally representative of the Taxi. This is the LEM LTA-8 which will be modified as necessary at MSC. Subsystems - Functionally and thermally complete subsystems with the LEM LTA-8, modified and reconditioned as necessary at MSC for manned T/V operations. Experiment Payload - None Major Facilities - MSC chamber "B" w/ACE, GSE (some mod's to chamber may be required for lunar storage simulation)	• Verify system operation with ACE after modifications at MSC. • Verify manned operation for ascent and rendezvous after quiescent lunar storage.

TABLE 3.3-8

TRUCK

GROUND TEST ARTICLES & FACILITIES

Item	Description	Purpose
Mock-Up Interior/Exterior Payload Interface M-1 Interior Ext. M-2 Payload Interface	Structure - Full scale wood and metal consisting of desc. stage with payload interface platform and landing gear. Truck desc. stage contains all subsystems, including RCS, for unmanned lunar landing with a payload. Portions of the SLA will be included. Subsystems - Full scale wood and metal Experiment Payload - Not required Major Facilities - None Note: Fluid lines only will be mocked-up (Elect. lines will be on ESI rig)	• Determine subsystems locations and fluid lines runs. • Determine payload interface details • Provide payload interface mock-up for experiment designer. • Demonstrate handling and transportation provisions. • Demonstrate SLA and GSE accessibility and service. • Demonstrate payload deployment for "1/6 g" with suited crew.
RCS Firing Rig R-1	Structure - Full scale metal skeleton of truck (desc. stage) without landing gear or adapter truss. Has correct geometry and interfaces for RCS structural, fluid, and electrical-connections and supports. Subsystems - Complete functioning, RCS of at least prototype level. Experiment Payload - None required. Major Facilities - Cold flow fac. & data Acq. White Sands (WSO) Hot Firing Altitude Chamber	• Evaluate and optimize RCS operations as re-located in the Truck (desc. stage) under cold-flow test conditions. • Verify RCS operation during hot-firing in altitude chamber.

TABLE 3.3-8 (cont)

Item	Description	Purpose
Test Model (Structural) TM-1	Structure - Full scale, structurally complete Truck descent stage with landing gear. Subsystems - All subsystems equipment, lines tanks and expendables will be mass represented. Experiment Payload - Mass, inertia, and response representation. Major Facilities - 4-shaker vibration system with data acquisition. Drop test tower with data acquisition. Minor static test equipment.	• Evaluate local structural stresses and deflections of subsystem supports in desc. stage for critical static loads. • Evaluate local structural stresses and deflections of payload platform for critical static loads. • Evaluate dynamic response of subsystem equipment and payload platform for critical vibration modes. • Evaluate dynamic response of subsystem equipment and platform for critical vibration modes. • Evaluate dynamic response of subsystem equipment and payload platform for critical landing impact.
Test Model (Thermal) TM-2	Structure - Full-scale thermal model of the Truck (desc. stage only) without landing gear or adapter trusses. These attachments and the RCS thruster mounts will be thermally simulated. A payload thermal simulator shall also be provided. Structure will not be loaded and does not require structural integrity. Electrical heaters will be installed on thermal shields and simulated hardware. Subsystems - Operating ECS heat transport section. Other subsystem equipment, lines, tanks and expendables are thermally simulated. Experiment Payload - Thermal model or simulation Major Facilities - Thermal-vacuum chamber with heater controls and data acquisition.	• Evaluate passive and active thermal controls for translunar and lunar descent phases. • Optimize subsystems location, support, and insulation. • Optimize payload platform support and insulation.

TABLE 3.3-8 (cont)

Item	Description	Purpose
Flight Control Simulator FCI	Structure - None required Subsystems - G & N, S & C and controls & displays of at least a prototype level for those components needed to simulate an unmanned lunar landing. Software programs as required. Experiment Payload - Mass & inertia parameters shall be supplied. Major Facilities - 3-axis table, torquers for sensors, data acquisition, computers	• Evaluate and optimize various unmanned lunar landing trajectories. • Evaluate and optimize lunar landing programs for various payload config. • Verify the selected programs with final parameters prior to launch. • Integrate FCS equipment.
Electr. Harness Integration & Checkout Rig ESI	Structure - Full scale metal skeleton of truck (desc. stage only) without landing gear or adapter truss. Has correct geometry & interfaces for all electrical and structural attachments for cable fabrication and checkout. Subsystems - Represented by electrical interfaces only such as splices, plugs, connectors, bus bars, or panels. Experiment Payload - Elect. interfaces only. Major Facilities - Minor automatic circuit checkout system. (DITMICO)	• Fabricate electrical and electronic harnesses and cables for each truck • Checkout cables during fabrication and build-up. • Prepare photographic lines installation drawings.
System Verification Test Article (Electronic) TTA-1	Structure - Complete truck structure (desc. stage) without landing gear or adapter truss. No requirement for structural integrity. No thermal insulation or thermal shielding is required. Subsystems - All subsystems will consist of functionally complete, operable equipment with ECS/GSE cooling and will be of at least prototype level. Experiment Payload - Same as subsystem Major Facilities - ACE (Minor EMI screen room and equipment also req'd)	• Electronic integration and functional testing of all subsystems with ACE & GSE. • Electromagnetic interference evaluation and control of operating subsystems combined with ACE & GSE • Verify electronic compatibility for all configurations or modifications

TABLE 3.3-8 (cont)

Item	Description	Purpose
System Verification Test Article (Environmental) TTA-2	Structure - Complete Truck structure (desc. stage) structurally and thermally representative. Modifications must maintain structural and thermal integrity. Subsystems - All subsystems will be functionally, structurally, and thermally complete and of at least a prototype level. Expendables will be mass and thermally simulated where they connot be present. Experiment Payload - Mass & thermal simul. Major Facilities - 4-shaker vibration system with data acquisition, ACE. Chamber "A" at MSC with CSM and ACE.	• Verify subsystem operation under mission level vibrations. • Verify subsystem operation in a thermal-vacuum environment during the descent phase following translunar flight as combined with Payload and CSM (at cham. "A" MSC)

4 PRELAUNCH OPERATIONS

4.1 PRELAUNCH OPERATIONS SCHEDULING

The Prelaunch Operations Planning for lunar mission AES-LEM configurations is based on the NASA launch schedule of 12 February 1965, AE 65-1(C). In summary, the prelaunch operations, from arrival at ETR through launch, require a period of from just short of 4 months to approximately 5 1/2 months, depending upon configuration. A composite picture of the prelaunch checkout activity scheduling for the lunar missions is shown in Fig. 4-1. The supporting information for each configuration's checkout operations is included within this section.

For reference purposes, the prelaunch activities for the initial LEM missions are indicated. The AES earth-orbital mission launch dates are also presented in Figure 4.1 for reference purposes. A maximum of four lunar missions per year is indicated in 1970 and 1971 which in conjunction with the earth orbital missions reflect an 8-mission per year total AES launch operation requirement.

4.2 PRELAUNCH CHECKOUT

Preliminary ETR checkout flows for the AES LEM Laboratory, Shelter, Taxi and Truck are presented. The functional subsystem configuration for each of the configurations investigated during Phase A are presented in Table 4-1.

The checkout flows summarized in Table 4-2 utilizes the current LEM ground operations requirements, [a] in conjunction with each AES-LEM configurations unique subsystem and experimental payload complement. In the cases of the two LEM Lab, and two Shelter configurations, where electrical power is derived from fuel cells rather than batteries, available prelaunch checkout planning information [b] from the original LEM configuration (with fuel cells) was used as a basis.

(a) GAEC Report LPL 610-3C - Lunar Excursion Module Ground Operations Requirements Plan, dated June 1965.

(b) GAEC Report LPL 610-3B - Lunar Excursion Module Prelaunch Checkout Plan (Test and Operations), dated January 1965.

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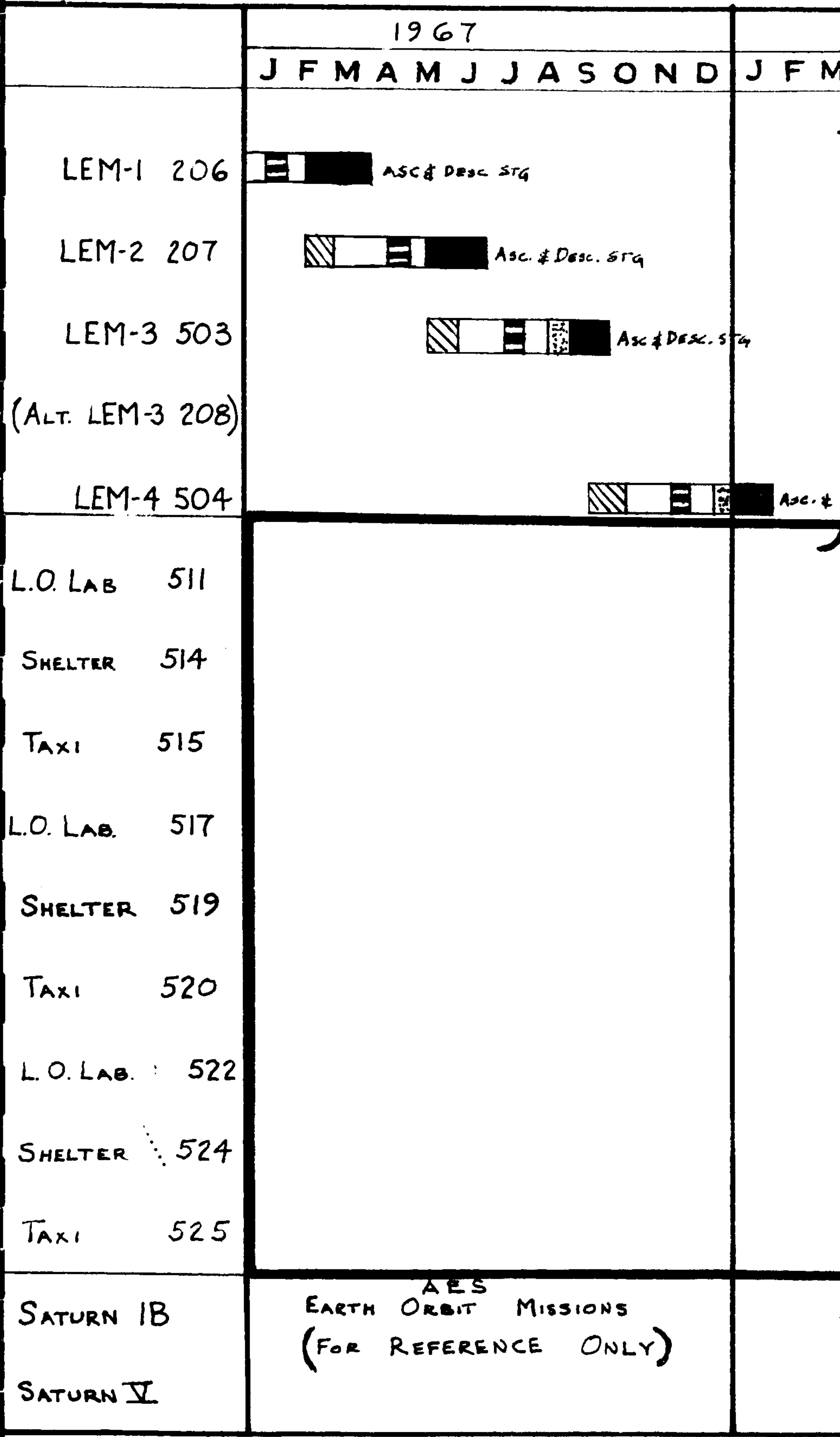

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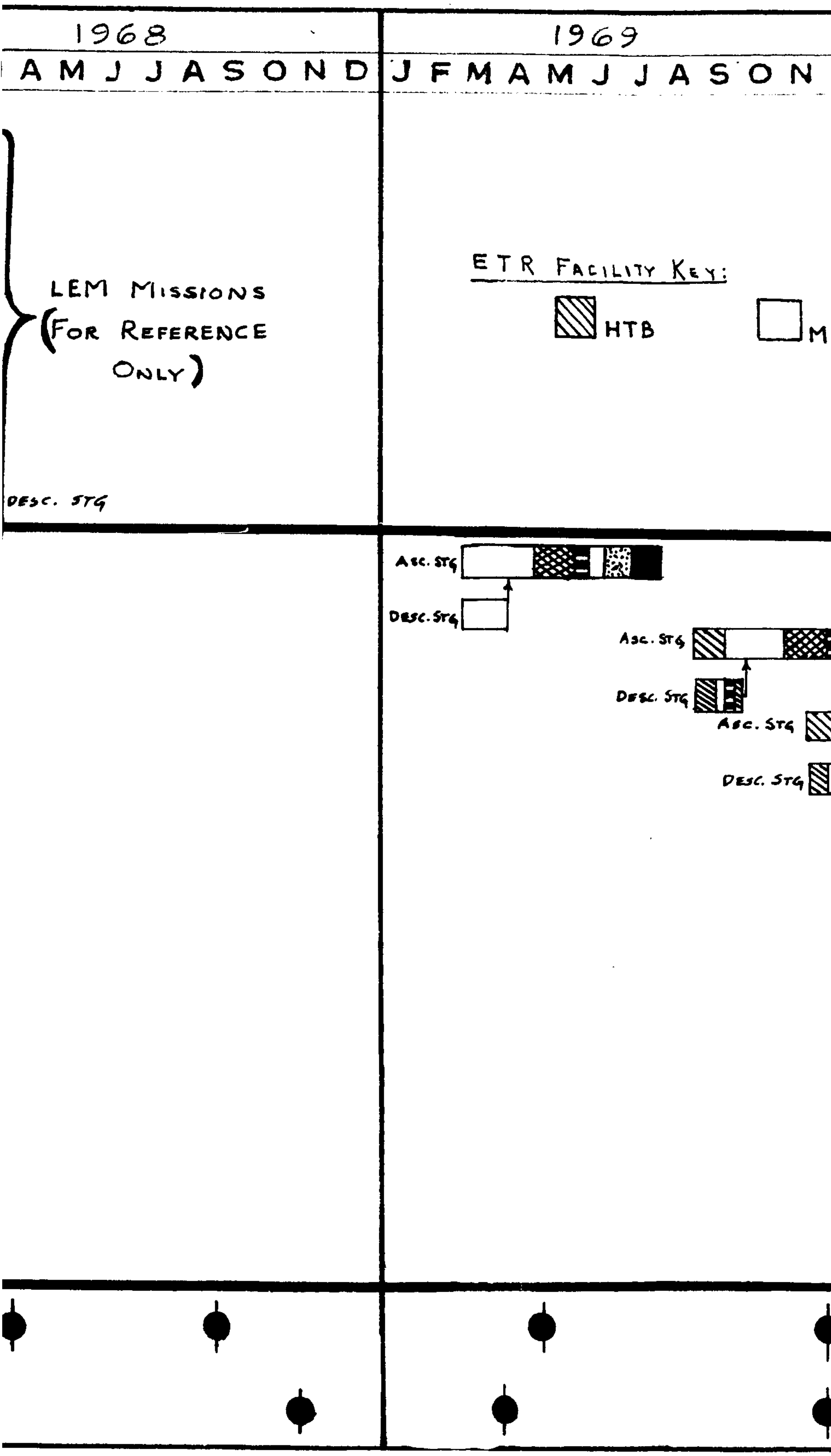

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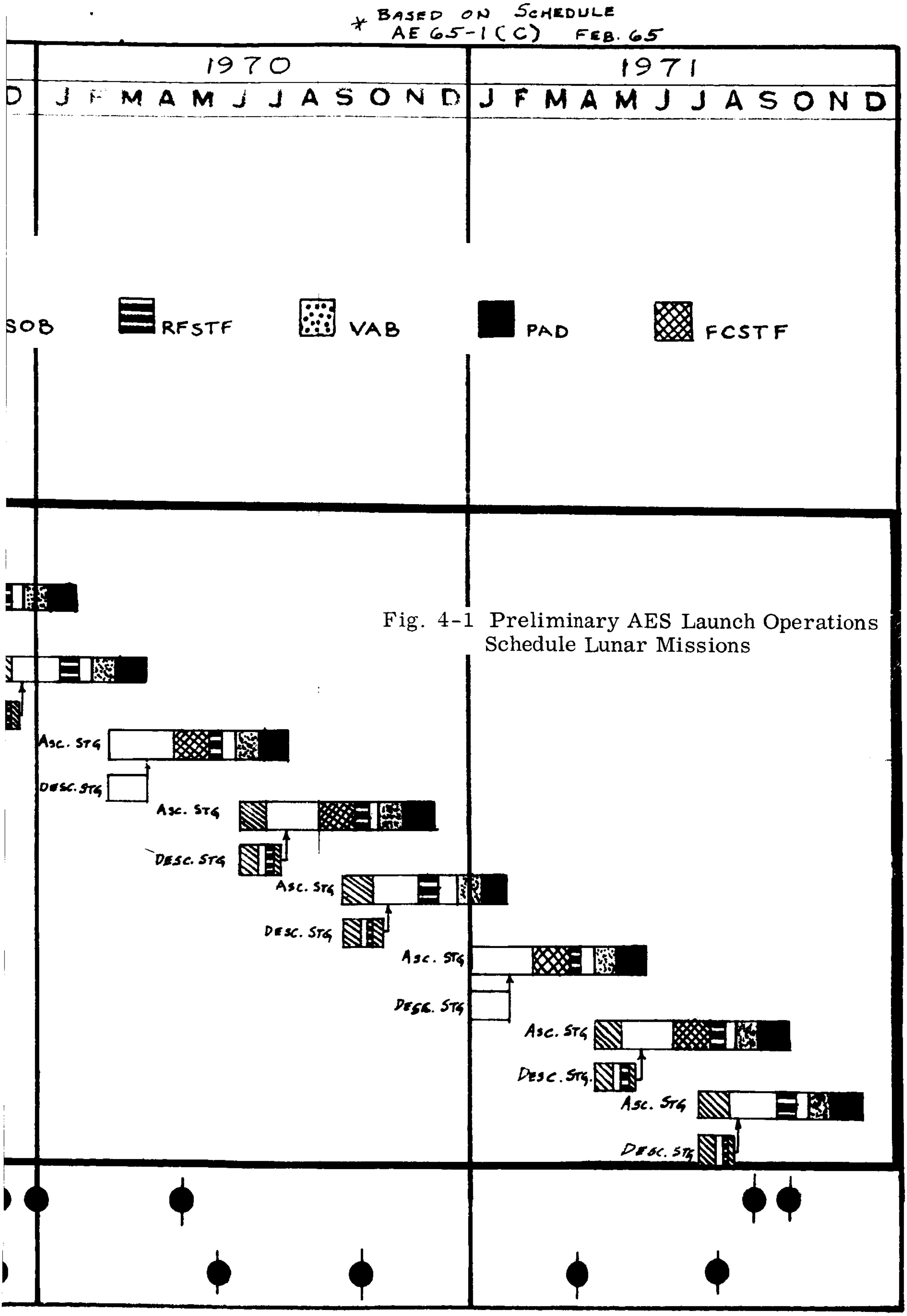

Fig. 4-1 Preliminary AES Launch Operations Schedule Lunar Missions

SUBSYSTEM	LABORATORY	
	Config. 1	Config. 2
Structure	Full A/S, Full D/S	Full A/S, L. P.
Stabilization & Control	Delete	Partial
Navigation & Guidance	Delete	Delete
Crew Provisions	Partial (No Waste Management)	Partial (No Wast Management)
Environmental Control	Reconfigure Use Heat Transport Loop, Add 0_2 Storage	Reconfigure Use Heat Transport Loop, Add 0_2 Storage
Landing Gear	Delete	Delete
Instrumentation	Partial (Reduction in Sensors)	Partial (Reducti in Sensors)
Electrical Power	Fuel Cells, Cryo Storage of Reactants	Fuel Cells, Cry Storage of Reac
Ascent Propulsion	Delete	Delete
Descent Propulsion	Complete	Delete
RCS	Delete	Delete
Communications	Intercom Only	Intercom Only
Controls & Displays	Add Experiment Displays	Add Experiment Displays

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TABLE 4-1

LEM UTILIZATION STUDY PHASE A CONFIGURATION SUMMA

	SHELTER		
	Config. 1	Config. 2	Config. 3
)/S	A/S, D/S	A/S, D/S (Plus)	A/S, D/S (Plus)
	Delete Abort Section	Delete Abort Section	Delete Abort Section
	Add Star Tracker & LMP	Add Star Tracker & LMP	Add Star Tracker & LMP
e	Complete (With Additions)	Complete (With Additions)	Complete (With Additions)
	Complete (Add GOX & Water)	Complete (Add Radiator and Integrate CSM Fuel Cell H_2O mgmt.)	Complete (Add Radiator and Integrate Gemini Fuel Cell H_2O mgmt.)
	Complete	Complete	Complete
n	Complete	Complete	Complete
) ants	Batteries	Fuel Cells, Cryo Storage of Reactants	Fuel Cells, Ambient Storage of Reactants
	Delete	Delete	Delete
	Complete	Complete	Complete
	Partial	Complete	Complete
	Complete with EVA TV Receiver Added	Complete with EVA TV Receiver Added	Complete with EVA TV Receiver Added
	Add Experiment Displays	Add Experiment Displays	Add Experiment Displays

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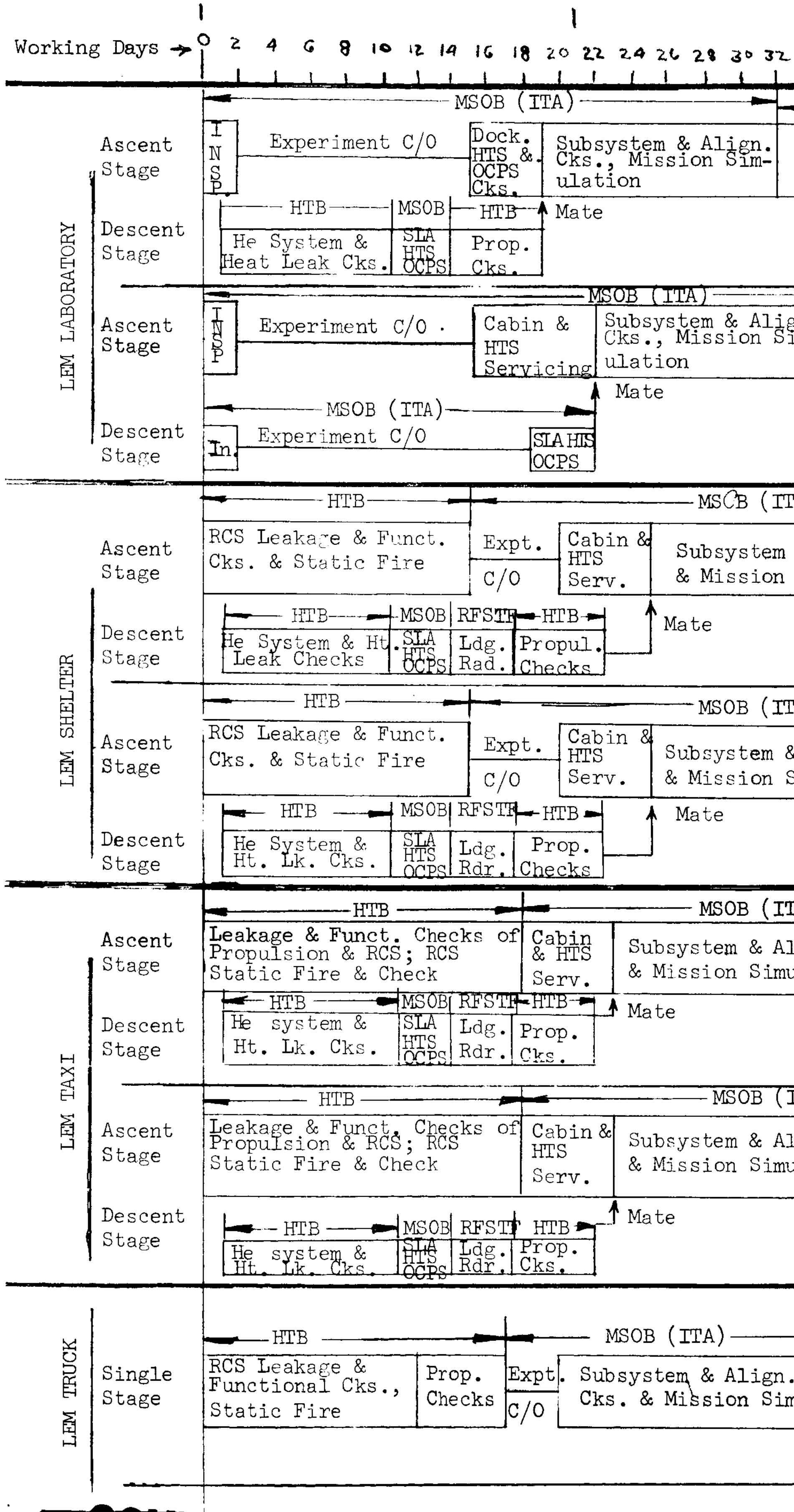
TAXI		TRUCK
Config. 2	Config. 5	Config. 1
A/S, D/S	A/S, D/S (Plus)	Delete A/S; D/S
Complete	Complete	Delete Abort Section
Complete	Complete	Add Star Tracker & LMP
Complete	Complete	Delete
Complete	Complete (With Additions)	Partial Same Components New Piping
Complete	Complete	Complete
Complete (Less Scientific Payload)	Complete (Less Scientific Payload)	Partial (Less Scientific Payload)
Batteries (3-7)	Batteries & RTG	Batteries
Complete	Complete	None
Complete	Complete	Complete
Complete	Complete	Partial (Relocate on D/S)
Complete (With Additions	Complete (With Additions)	Partial (With Modifications)
Complete	Complete	Delete

Table 4-1

[redacted]

TA



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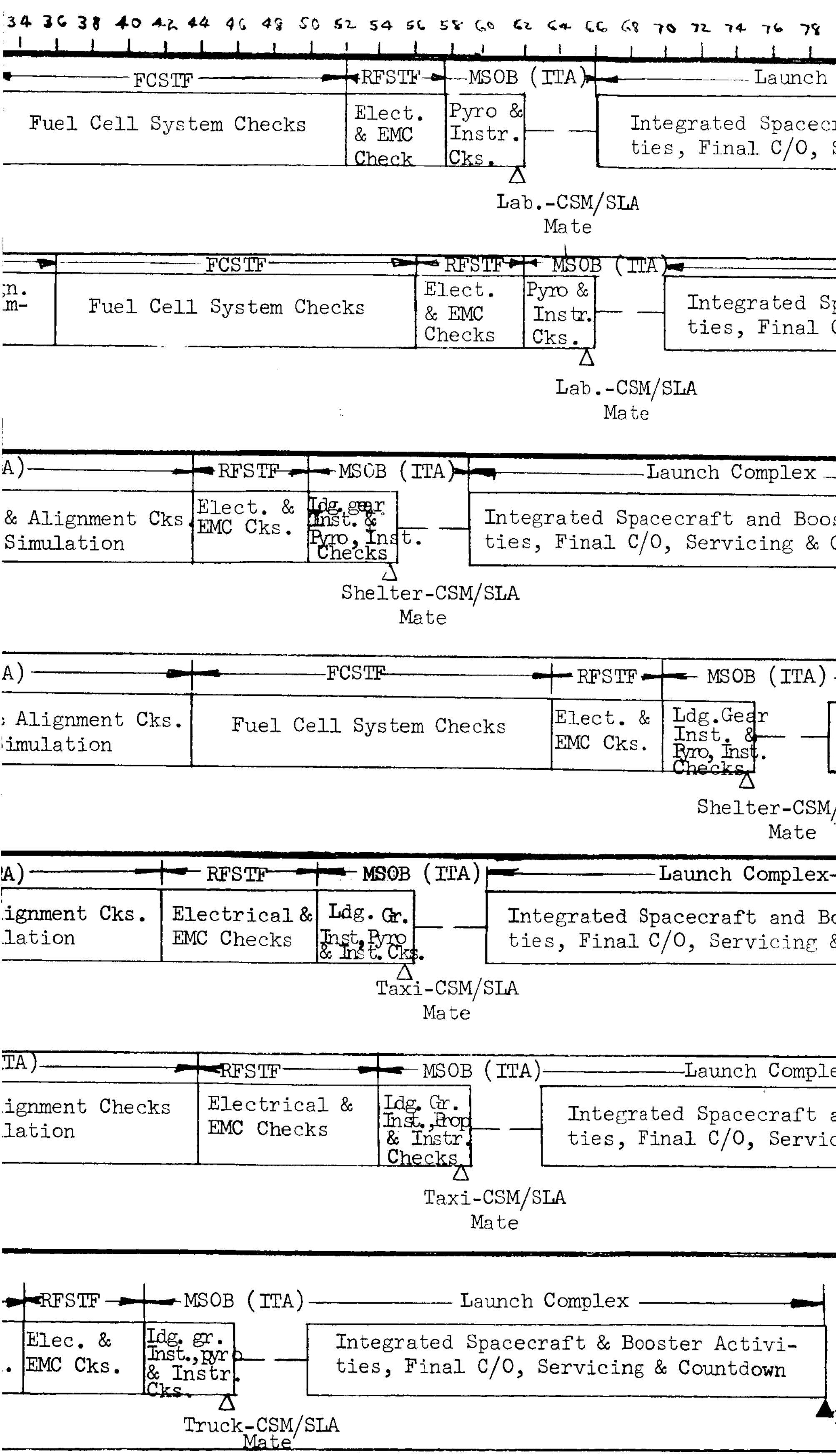
ABLE 4-2. PRELIMINARY ET[redacted]EM UTILIZATION STUDY P



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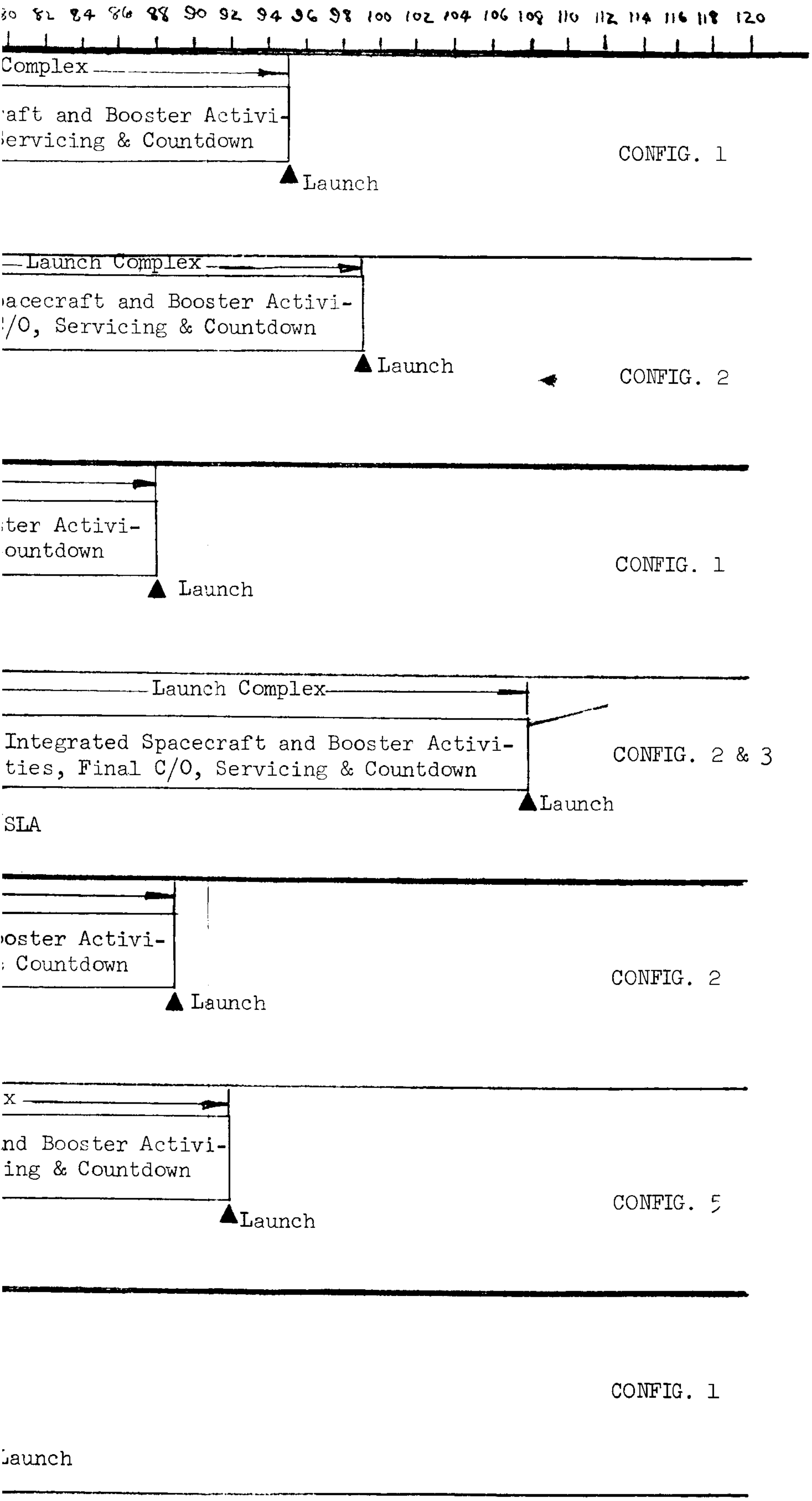
2

HASE A

4-7/4-8



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3

4.3 GUIDELINES

The following list of general guidelines were utilized during the course of the LEM Utilization Study - prelaunch checkout planning.

- The current or basic LEM ETR flow time span equivalent to 90 working days (nominal).
- Preliminary CSM and booster flow requirements:

  (a) CSM - Mating with AES-LEM 34 working days prior to launch.

  (b) Booster - Integrated spacecraft - booster activities demand a total of 29 working days.

- For preliminary planning purposes, no distinction is made between Saturn V VAB-PAD activities (Complex 39) and Saturn IB (Complex 37B) activities.
- Detailed experiment payload checkout will be performed on the Lab configurations. Minimal experiment payload is expected on the Taxi configurations. For the Truck configuration, the payload is assumed to be independent.

4.4 VEHICLE TIME FLOWS

The following table summarizes the respective KSC prelaunch checkout time spans. As indicated in the table, the differences between vehicle checkout total times is small. The largest increments over the nominal 90 day prelaunch checkout for the current LEM are in the optimized LEM Lab configuration and is attributable to the combination of: addition of fuel cell EPS in lieu of a battery EPS and additional of experiment payloads.

Total Working Days*

AES Vehicle	Vehicle Configuration	
	Minimal Change From LEM	Mission Optimized
Laboratory	95	99
Shelter	88	108
Taxi	89	92
Truck	--	79

*The working days are currently defined as a five day week with a two-shift operation. The weekend and the third shift are to be utilized for contingencies.

An indication of the KSC facility utilization for each AES-LEM spacecraft is presented in the following table:

	Laboratory				Shelter				Taxi				Truck	
	1		2		1		2 & 3		2		5		1	
	*ASC	DES	*ASC	DES	*ASC	DES	*ASC	DES	*ASC	DES	*ASC	DES	*ASC	DES
HTB		•			•	•	•	•	•	•	•	•	•	•
MSOB	•	•	•	•	•	•	•	•	•	•	•	•	•	•
FCSTF	•		•				•							
RFSTF	•		•		•	•	•	•	•	•	•	•	•	•
Launch Complex	•		•		•		•		•		•		•	

*Ascent also includes the mated configuration.

4.4.1 LEM Lab - Configuration 1

The prelaunch checkout period of 95 working days for this Lab configuration is characterized by the following features:

1. A basic experiment checkout period (13 days).
2. A fuel cell system checkout period (20 days).
3. Omission of the LEM ascent engine checkout requirements (by deleting the ascent propulsion subsystem).
4. Deletion of landing gear and attendant requirements.

The experiment payload is assumed to be primarily located in the ascent stage.

4.4.2 LEM Lab - Configuration 2

The prelaunch checkout period of 99 working days for this Lab configuration is characterized by the following features:

1. Deletion of all propulsion and reaction control subsystems.
2. A basic experiment checkout period (17 days).
3. A fuel cell system checkout period (20 days).
4. Deletion of landing gear and attendant requirements.

The experiment payload is assumed to be primarily suspended from the low profile descent stage.

4.4.3 LEM Shelter - Configuration 1

The prelaunch checkout period of 88 working days for this Shelter configuration is characterized by the following features:

1. Ascent stage RCS testing rather than RCS plus ascent engine tests, since the LEM ascent propulsion subsystem is deleted.
2. A nominal five-day period for experiment checkout of the experimental payload located in the ascent stage and three days for descent stage experiment payload.
3. Implementation for an unmanned landing.

4.4.4 LEM Shelter - Configuration 2

The prelaunch checkout of 108 working days for this Shelter configuration is characterized by the three features listed under Shelter Configuration 1 and the following:

1. A fuel cell system checkout period (20 days).

4.4.5 LEM Shelter - Configuration 3

This configuration is similar to configuration 2; however, Gemini fuel cells are used instead of CSM fuel cells.

4.4.6 LEM Taxi - Configuration 2

The prelaunch checkout period of 89 working days for this Taxi configuration is characterized by close similarity to the basic LEM vehicle. The electrical power generation is provided by a group of batteries varying in number from 4 to 7 depending on whether the Taxi mission is for lunar day or lunar night.

4.4.7 LEM Taxi - Configuration 5

The prelaunch checkout of 92 days for this Taxi configuration is similar to the Taxi Configuration 2, in that it too bears a close similarity to the basic LEM. However, this configuration embodies additions in the basic Structure, Environmental Control Subsystem and Electrical Power Subsystem. The principal addition to checkout requirements is for the Radioisotope Thermal Generator.

4.4.8 LEM Truck

The Truck configuration prelaunch checkout of 79 working days is characterized by a single stage configuration. The vehicle is essentially a modified LEM descent stage. Many of the LEM ascent stage functional checkouts will be performed on the vehicle (or descent stage). The major features which the Truck embodies are:

1. LEM RCS relocated on the descent stage.
2. Modified electrical subsystems relocated on the Truck, notably SCS and NGS.
3. Utilization of LEM ECS components, with piping modified.
4. Implementation for an unmanned landing.

4.5 FUTURE STUDY

The need for additional study exists in several areas of prelaunch checkout development. Essentially these needs are for refining the preliminary work, specifically, the three major efforts which should be undertaken are:

- Detail the prelaunch checkout procedures for each unique AES LEM configuration.
- Define interfaces with experiments, booster and CSM in more detail.
- Determine the impact on KSC facilities, new facility activation and scheduling for an integrated AES-LEM program. Closely associated with the facilities study are the related KSC GSE requirements for the prelaunch checkout of each unique vehicle.

5. SUPPORT

5.1 INTRODUCTION

The objective of the support effort during this study was to determine, in gross terms, the extent of unique support hardware and software requirements for the representative LEM AES configurations. Those support requirements which are common to the existing LEM program were examined for compatibility but not for adequacy and availability.

5.2 ASSUMPTIONS

The following assumptions were established for this study effort, and will be updated and modified as needed throughout subsequent phases of the program:

- For all experiments, the GSE, astronaut training and experiment simulators will be the responsibility of the experimenter.
- All LEM support equipment, applicable to the AES will be available and no conflict in schedule with LEM exists.
- The Launch Complex will be the same as that for LEM.
- Modifications to LEM GSE will not interfere with the LEM program.
- ACE-S/C will be the prime item of electronic checkout equipment.
- ACE-S/C will not be used to checkout the experiments.
- Four sets of GSE will be required for the program, (2 sets at Grumman, 1 set KSC, 1 set MSC).
- Only the requirements for unique items of support equipment were considered.
- The impact on programming ACE-S/C was not considered.
- The fuel cells will be the same as those used on the CSM or Gemini.

5.3 SUPPORT REQUIREMENTS

The gross support requirements for the representative configurations are summarized in Tables 5.3-1 through 5.3-4.

5.3.1 Lab Gross Support Requirements

The major impact on support for the Lab is brought about by the addition of fuel cells, a new electrical power distribution system, increased oxygen storage requirements and modifications to the LEM structure and ECS heat transfer loop in both configurations.

5.3.1.1 Ground Support Equipment

Test equipment for EPS will be required at Grumman for acceptance, integration and maintenance of the fuel cells and the inverter. Use of the CSM type fuel cell and inverter may permit the use of modified CSM support equipment at AMR and common usage support equipment at Grumman. The use of fuel cells will require cryogenic storage and distribution of oxygen and hydrogen. This requires a considerable quantity of cryogenic handling, checkout and servicing equipment. Since Grumman had originally intended to use fuel cells on LEM, a significant portion of the necessary equipment has been investigated. For example, the cryogenic transfer system has been designed and there is a working breadboard of the fuel cell startup equipment. These equipments will be further examined to determine their applicability to the Lunar Orbiting Lab.

An Electronic Systems Integration (ESI) Test will be required for each configuration due to changes in the wiring. Most of the support equipment and some unique assemblies can be used interchangeably for all configurations. Assuming the use of ACE S/C for ESI testing of new programs, new peripheral equipment, adapters and breakout boxes will be required. In addition, the interface to experiment equipment, and to CSM subsystems, including GNCS and Communications will have to be simulated.

Much of the existing LEM support equipment for the ECS can be utilized. The following items fall into this category:

- Water servicing manifold
- water separation discharge accumulator
- water management section servicing vacuum pump
- Cabin Leak Test Unit
- Helium-Hydrogen Leak Detector

In addition certain major items of equipment require only minor modification:

- Gaseous oxygen component test stand
- Water glycol component test stand
- Water component test stand
- Water glycol trim control unit.
- Water transfer unit
- Freon supply cart.
- Freon bottle rack manifold
- Gaseous oxygen transfer unit

New support equipment will be required for the development, acceptance and qualification testing of radiators, and for verification of the cooling loops. Changes in the vehicle configuration and alignment requirements of the mapping mission will require additional mechanical GSE and in certain cases modifications to existing LEM GSE. Modifications to the following equipment will probably be required:

- Moment of inertia stand
- Turn-over fixture
- Cleaning fixture
- Internal servicing platforms (NAA design)

5.3.2 Shelter Gross Support Requirements

A major portion of the existing LEM support equipment can be used intact, or modified to support the Shelter development and site requirements. Additional support equipment will be necessary for the automatic tracker assembly, activation sequencer, fuel cells, and cryogenic units. Although many of the LEM spare parts can be utilized, some additional items are required in support of the new or modified subsystems. Additional publications, training, support requirements are significant for the Shelter configurations analyzed.

5.3.2.1 Ground Support Equipment

It is anticipated that the proposed modifications will generate the following major support requirements.:

A) Modification of existing test equipment associated with each of the following subsystems to support integrity and performance tests of each reconfigured subsystem:

- Guidance and Navigation
- Environmental Control
- Electrical Power
- Reaction Control
- Instrumentation
- Communication
- Stabilization and Control

B) Checkout, qualification test, bench maintenance and carry-on equipment for support of the automatic tracker assembly, the activation sequencer and the fuel cell assembly and cryogenics unit. It should be noted that the checkout equipment for the auto-tracker assembly will be similar to the OAO star-tracker support equipment which consists of a unit that produces all necessary input signals, has the ability of deciphering all signals and is used in conjunction with a star simulator unit.

C) New test rigs including wiring harnesses are required to support the electronic system integration tests for the two Shelter configuration.

D) Assuming the use of ACE S/C for the ESI testing new programs, new peripheral equipment, adapters and breakout boxes will be required.

E) New Internal Servicing Platform (NAA design).

5.3.3 Taxi Gross Support Requirements

Taxi configurations are similar to the LEM. Because of this, the GSE designed for, and utilized on the LEM, will to a large extent be suitable for the LEM Taxi. Modifications will be required to the carry-on, and bench maintenance equipment in the areas of communications, instrumentations, and electrical power subsystems.

5.3.3.1 Ground Support Equipment

Support equipment for mechanical, electrical, and thermal testing of the thermal shields for the top hatch and RCS thrusters and the window shades will be required during development, acceptance, and integration with the Taxi. Special testing and handling rigs will be needed for mechanical and electrical development. Handling equipment for thermal vacuum chamber tests will also be required.

An additional large impact on support stems from the incorporation of an RTG (radio-isotope thermal generator) unit in configuration five. This RTG will be similar to the RTG that will be incorporated with a scientific package on the LEM. Special Support equipment for transportation, handling, and installation will be required at installation facilities and at sites.

Incorporated with the RTG will be a heat pipe which will require support equipment for development, handling and spares.

5.3.4 Truck Gross Support Requirements

A major portion of the existing LEM support equipment can be used intact, or modified to support the Truck development and site requirements. Additional support equipment is required for the modified and reconfigured subsystems.

5.3.4.1 Ground Support Equipment

It is anticipated that the proposed design will generate the following major support requirements:

- New equipment for support of Truck, vibration and moment of inertia test.
- Weight and Balance Fixture
- Adapter Fixture

Modification of existing test equipment associated with each of the following subsystems to support integrity and performance tests of each modified and reconfigured subsystem.

- Guidance and Navigation
- Environmental Control
- Electrical Power System.
- Reaction Control System
- Instrumentation
- Communication
- Stabilization and Control

Checkout, qualification test, bench maintenance and carry on equipment for support of the automatic tracker assembly and the activation sequencer. It would be noted that the checkout equipment for the automatic tracker assembly will be similar in nature to the OAO star tracker support equipment. This equipment consists of a unit that produces all necessary input signals, has the ability of deciphering all output signals and is used in conjunction with a star simulator unit.

- New test rig is required to support the Truck electronic system integration tests.
- New antenna alignment equipment is required relative to tests verifying antenna patterns.
- New descent stage handling and hoisting equipment is required including a new hoisting fixture.
- New cleaning and turnover fixture.
- New internal servicing platform.

TABLE 5.3-1

LO LAB SUPPORT SUMMARY

VEHICLE AND CONFIGURATION	SUPPORT EQUIPMENT	TRAINING	PUBLICATIONS	SPARES
Lunar Orbit Labs Configurations 1 and 2	• ACE S/C Equipment Carry-On Adapters Peripheral Equipment Program • Radiator Test Equipment • Fuel Cell Support Equipment • Cryogenic Handling Servicing and Checkout Equipment. • Inverter Test Equipment • ESI Support Equipment • Horizon Scanner Support Equipment • ECS Support Equipment to be modified or replaced. Water Glycol Trim Control Water Transfer Unit Freon Supply Cart Freon Bottle Rack and Manifold Gaseous Oxygen Transfer Unit • Support Equipment for Data Storage Equipment • Mechanical Alignment Equipment • Vibration Adapters	• Modify LEM Training Programs • New Mission Trainer	Slight modification and additions because of new subsystems, with new maintenance and repair manuals for the • EPS • ECS • Instrumentation • S & C	• Provision initial Spares support for: EPS ECS Instrumentation Controls & Displays Horizon Sensor

TABLE 5.3-2
SHELTER SUPPORT SUMMARY

VEHICLE & CONFIG	SUPPORT EQUIPMENT	TRAINING	PUBLICATIONS	SPARES
SHELTER CONFIGURATION #1	• New Electronic Systems Integration Test Rig • Modify integrity and performance test requirements for the reconfigured subsystems: Navigation and Guidance, Environmental Control, Electrical Power, Reaction Control, Instrumentation, Communications, Stabilization and Control. • Automatic Tracker: Checkout, qualification test, bench maintenance and carry-on equipment.	• Revision of current LEM Training Courses • New Mission Trainer	• Revision of current manuals in Maintenance Repair, Apollo Operation Handbook Operational Checkout, GSE Manuals, and Site Activation Operational Checkout Procedures. • Maintenance Repair Manuals for Automatic Star-Tracker, ESI Rig and the associated support equipment.	• Provision initial Spares support for: modified portions of existing equipments, Auto-Tracker, ESI Test Rig and the associated support equipment. • Reprovision identical LEM spares which are high usage, non-repairable items. • Reprovision identical LEM spares which are limited shelf life items.

TABLE 5.3-2 (cont)

SHELTER SUPPORT SUMMARY

VEHICLE & CONFIG	SUPPORT EQUIPMENT	TRAINING	PRUBLICATIONS	SPARES
SHELTER CONFIGURATION #2	• Include all above items. • Activation Sequencer: Checkout, qualification test, bench maintenance, and carry-on equipment. • Fuel Cell Assembly: Checkout, qualification test, bench maintenance and carry-on equipment. • Cryogenics Units: Checkout, qualification Test, bench maintenance and carry-on equipment.	• Include all above items, plus reference to Activation Sequencer, Fuel Cell Assembly and Cryogenic Units and the associated support equipment.	• Include all above items, plus reference to Activation Sequencer Fuel Cell Assembly and Cryogenic Units and the associated support equipment.	• Same as above, plus spares for FCA, Cryogenics Unit and Activation Sequencer and the associated support equipment.
CONFIGURATION #3	• Ambient reactant tanks: checkout, qualification test, bench maintenance, and carry-on equipment.	• Ambient reactant tankage.	• Ambient reactant tankage.	• Ambient reactant tankage.

TABLE 5.3-3 (cont)
TAXI SUPPORT SUMMARY

VEHICLE & CONFIG.	SUPPORT EQUIPMENT	TRAINING	PUBLICATIONS	SPARES

TAXI CONFIGURATION 2	• Test Rigs for:
	  • Mechanical Structural Tests of Top Hatch Thermal Shield
	  • RCS Thruster Cover Mechanism
	  • Window Shades and Mechanism
	• Handling Equipment for Thermal Vacuum Chamber Tests
	• Modify Bench Maintenance Equipment for:
	  • Instrumentation
	  • Communications
	• Modify Carry-on Equipment
		• Slight Modification to Trainers
		• Slight modification to Training Programs.
			• Slight modification and additions.	• Top Hatch Thermal Shields
				• RCS Thruster Thermal Shields and Mechanisms
				• Window Shades and Mechanisms

TAXI SUPPORT SUMMARY

VEHICLE & CONFIG.	SUPPORT EQUIPMENT	TRAINING	PUBLICATIONS	SPARES

TAXI CONFIGURATION 5	• Test Rigs for:
	  • Mechanical Structural Tests of Top Hatch Thermal Shield
	  • RCS Thruster Cover Mechanism
	  • Window Shades and Mechanism
	• Handling Equipment for Thermal Vacuum Chamber Tests
	• Modify Bench Maintenance Equipment for:
	  • Instrumentation
	  • Communications
	  • Electrical Power
	• Storage Rig for RTG
	• Handling and Transportation Rigs for RTG
	• Installation Rig For RTG
	• Modify Carry-on Equipment
		• Slight modification to Trainers	• Slight modification and additions.	• Top Hatch Thermal Shields
				• RCS Thruster Thermal Shields and Mechanisms.
				• Window Shades and Mechanisms
				• RTG Units
				• Heat Pipe Components

TABLE 5.3-4

TRUCK SUPPORT SUMMARY

VEHICLE AND CONFIGURATION	SUPPORT EQUIPMENT	TRAINING	PUBLICATIONS	SPARES
TRUCK	• Weight and Balance Fixture • Adapter Fixture • Modify integrity and performance test equipment for reconfigured Guidance and Navigation, Environmental, Control Electrical Power System, Reaction Control Stabilization and Control and Instrumentation and Communication. • Automatic tracker assembly checkout, qualification test, bench maintenance and carry-on equipment. • Activation Sequencer, checkout, qualification test, bench maintenance and carry-on equipment. • Test rig for ESI Tests. • Antenna alignment equipment • Descent stage handling and hoisting equipment	• Revision of Current LEM Training Courses	• Revision of current LEM manuals in areas of Maintenance Repair, Transportation and Handling, Apollo Operation Handbook, Operational Checkout, GSE Manuals and Site Activation Operational Checkout Procedures.	• Provision initial spares support for the modified portions of existing equipment and the new Automatic tracker and Activation Sequencer components.

TABLE 5.3-4

TRUCK SUPPORT SUMMARY

(Continued)

VEHICLE AND CONFIGURATION	SUPPORT EQUIPMENT	TRAINING	PUBLICATIONS	SPARES
TRUCK	• Descent stage cleaning and turnover fixture • Internal Maintenance Servicing Platform • Modify the descent stage transportation equipment. • Payload hoisting and transportation equipment, handling assembly and tiedown kit.			

6. MANUFACTURING PLAN

6.1 INTRODUCTION

Preliminary task definitions, manufacturing schedules and fabrication costs for each AES configuration were developed during the phase "A" study. The cost and schedule analysis was based on the following assumptions:

- Maximum utilization of LEM technology, hardware, tooling, equipment, and facilities without interfering with or affecting the LEM program schedule or costs.
- All vehicles will be production line modifications.
- LEM hardware components will be retained in their original locations whenever possible.
- Additional penetrations of the ascent stage pressure shell will be permitted only when demanded by experiments.
- Design effort will standardize locations of experiments, electrical power supply, and additional environmental control system components.
- The "Drape" method of installation of the thermal and micrometeoroid shielding will be employed, although the thickness is anticipated to be double that of the present LEM.

6.2 DESIGN AND DEVELOPMENT

To support the design and development phase of the AES Program the following test articles will require modifications to existing LEM hardware or fabrication of new items. The tabulation below is predicted on the basis that only one of the configurations is under development. For the complete AES Program a qualitative summation of test articles is required as shown in section 3.0.

TAXI

- Thermal Test Model LEM TM-2 modified to the Taxi configuration maintaining cabin structural and leakage integrity. Systems other than ECS are thermally simulated.
- Structural Test Element Full scale structural element representing the battery installation.
- ESI-T Full scale ascent/descent metal skeleton.
- TLTA-1 LEM LTA-8 modified to structurally and thermally represent the Taxi.

SHELTER

- Mock-up Full scale wood and metal ascent and descent stages with landing gear and subsystem representations.
- Thermal Test Model TM-2 modified from Taxi to Shelter configuration, systems other than ECS are thermally simulated.
- ESI-S Full scale ascent/descent metal skeleton.
- SLTA-1 Complete ascent/descent stages with landing gear structurally and thermally representative of the Shelter, leakage integrity must be maintained.

LAB

- Mock-up Full scale wood and metal ascent and descent stage* with landing gear and subsystems representations.
- Thermal Test Model Full scale ascent and descent* stages with a CSM thermal simulator. Cabin shall maintain leakage integrity. Systems other than ECS are thermally simulated.
- Power Generation Simulator Thermal model of structure supporting and surrounding fuel cell power generation system. ECS, EPS and instrumentation as required for operation and temperature control.

*A low profile descent stage will replace the 68" descent stage on Configuration 2 Lab Models.

- ESI-L Full scale metal skeleton of ascent/descent*stage.

- LLTA-1 Complete ascent/descent* structure representation. No pressurization leakage, structural, or thermal requirements.

- LLTA-2 Complete ascent/descent* stages structurally and thermally representative of the lab configuration. Cabin leakage integrity must be maintained. Subsystems will be structurally and thermally representative of qualified equipment.

TRUCK

- Mock-up Full scale wood and metal descent stage containing representative subsystems and payload interface platform.

- RCS Firing Rig Full scale metal skeleton without landing gear. Complete reaction control system.

- Structural Test Model Full scale descent stage with landing gear. Subsystems will be mass represented.

- Thermal Test Model Full scale thermal model without landing gear.

- ESI-TR Full scale metal skeleton of Truck without landing gear.

- TTA-1 Complete Truck without landing gear. No structural or thermal requirements. Subsystems will be functionally operable prototypes.

- TTA-2 Complete Truck structure representative of thermal and structural integrity. Subsystems will be functionally operable prototypes.

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*A low profile descent stage will replace the 68" descent stage on Configuration 2 Lab Models.

6.3 TOOLING

A basic guideline of the study assumes that all LEM tooling and facilities will be available, on a non-interference basis, to the AES Program.

The following tooling is required due to configuration change only; no rate tooling is required:

NOTE: *Indicates the tooling required for two or more vehicle configurations.

TAXI (configuration 5)

- * Detail and assembly tooling for RTG support structure in descent stage.
- * Detail and assembly tooling for heating panel support structure in ascent stage.

LAB (configuration 1)

- * Detail and assembly tooling for fuel cell support structure.
- * Installation tooling for viewfinder.
- * Fabrication and assembly tooling for modified ascent engine cover.
- * Detail, assembly and installation tooling for FCA equipment radiators.
- Installation fixture for panoramic cameras.
- * Detail tooling for support trusses replacing ascent propulsion tanks.

LAB (configuration 2)

- Adapter to present LEM descent stage fixture for sub and final assembly of low profile descent stage.
- * Installation tooling for viewfinder.
- * Fabrication and assembly tooling for fuel cell support structure.
- * Detail, assembly and installation tooling for FCA equipment radiators.
- Installation fixture for panoramic cameras.
- * Fabrication and assembly tooling for modified ascent engine cover.
- * Detail tooling for support trusses replacing ascent propulsion tanks.

SHELTER (configuration 1)

- * ● Installation tooling for sleeping and hygienic facilities.
- * ● Fabrication and assembly tooling for modified ascent engine cover.
- * ● Detail tooling for support trusses replacing ascent propulsion tanks.
- * ● Detail, assembly and installation tooling for docking hatch cover.
- ● Detail, assembly and installation tooling for GOX tankage support structure.
- ● Detail and assembly tooling for additional batteries in descent stage.

SHELTER (configuration 2)

- * ● Installation tooling for sleeping and hygienic facilities.
- * ● Fabrication and assembly tooling for RTG support structure in descent stage.
- * ● Fabrication and assembly tooling for heating panel support structure in ascent stage.
- * ● Fabrication and assembly tooling for modified ascent engine cover.
- * ● Detail tooling for support trusses replacing one ascent propulsion tank.
- * ● Detail, assembly and installation tooling for docking hatch cover.
- * ● Fabrication and assembly tooling for fuel cell support structure.

SHELTER (configuration 3)

- * ● Installation tooling for sleeping and hygienic facilities.
- * ● Fabrication and assembly tooling for RTG support structure in descent stage.
- * ● Fabrication and assembly tooling for heating panel support structure in ascent stage.
- * ● Fabrication and assembly tooling for modified ascent engine cover.
- * ● Detail tooling for support trusses replacing one ascent propulsion tank.
- * ● Detail, assembly and installation tooling for cocking hatch cover.
- ● Fabrication and assembly tooling for fuel cell support structure.
- ● Detail, assembly, and installation tooling for FCA equipment radiators.

TRUCK

- Detail and installation tooling for RCS tankage module.
- Final assembly fixture for addition of RCS, ECS, etc.
- Detail, assembly and installation tooling for navigation base.
- Alignment fixture for alignment of IMU, startracker, etc.
- Detail tooling for subsystem support structure.

6.4 PRODUCTION

Configuration changes will be scheduled for implementation during the fabrication and final assembly operations. The sequence of structural fabrication and assembly for all vehicle configurations is similar to that of the LEM. The major deviations from the basic LEM that affect the manufacturing effort are:

TAXI (configuration 2)

- Modification of the coolant to bypass the IMU and ASA.
- Additional battery installations.
- Fabrication and installation of upper hatch cover.
- Additional insulation around batteries and water tank.
- Change water tank support structure.

TAXI (configuration 5)

- Modification of the coolant loop to bypass the IMU and ASA.
- Fabrication and installation of upper hatch cover.
- Additional insulation around batteries and water tank.
- Change water tank support structure.
- **Install RTG system including heating panel in ascent stage.**

LAB (configuration 1)

- Ascent propulsion system deleted.
- Reaction control system deleted.
- Guidance and navigation system deleted.
- Stabilization and control system (DECA excepted) deleted.
- Two fuel cell assemblies and three cryogenic supply tanks replace batteries.
- Addition of ECS equipment radiator system.
- Installation of two large panoramic cameras and associated experiment packages.

LAB (configuration 2)

- Ascent and descent propulsion systems deleted.
- Reaction control system deleted.
- Guidance and navigation system deleted.
- Stabilization and control system partially deleted.
- Fabrication and assembly of low profile descent stage.
- Two fuel cell assemblies and three cryogenic supply tanks replace batteries.
- Addition of ECS equipment radiator system.
- Suspension of two large panoramic cameras from the low profile descent stage and associated experiment packages.

SHELTER (configuration 1)

- Ascent propulsion system deleted.
- Additional battery, oxygen tankage and water tankage installations.
- Installation of sleeping, hygienic and work area facilities.
- Fabrication and installation of upper hatch cover.
- Installation of automatic unmanned landing system.

SHELTER (configuration 2)

- Ascent propulsion system deleted.
- Installation of fuel cell assembly and cryogenic supply tankage.
- Installation of sleeping, hygienic and work area facilities.
- Fabrication and installation of upper hatch cover.
- Installation of RTG system in descent stage and heating panel in ascent stage.
- Installation of automatic unmanned landing system.
- Installation of equipment radiators.

SHELTER (configuration 3)

- Same as above.
- Installation of fuel cell assembly and ambient reactant tankage.

TRUCK

- Entire ascent stage structure deleted.
- Installation of reaction control system.
- Installation of environmental control system (life support deleted)
- Installation of coolant evaporator.
- Installation of navigation base, IMU and startracker.
- Installation of automatic unmanned landing system.

6.5 FINAL ASSEMBLY AND ACCEPTANCE TESTING

Final assembly and acceptance testing of all vehicle configurations will be accomplished utilizing the existing LEM facilities. The sequence of installation of required systems will be identical for all vehicles.

Figures 6-1 thru 6-8 illustrate the final assembly flow of the major structural components and/or systems required for each configuration.

The typical final assembly and acceptance test sequence of operations is as follows:

ASCENT STAGE

- Rotate and clean structure.
- Install required subsystems (EPS, ECS, RCS, Propulsion), associated plumbing, electrical harnesses, leak check plumbing and conduct DITMCO checkout.
- Cold flow ECS, RCS and Propulsion subsystems and as applicable EPS subsystem.
- Rotate and clean vehicle.
- Install antennas, associated "black boxes" and experiment packages.
- Conduct ascent stage verification tests of systems.
- Mate with descent stage and vibrate. Demate following vibration tests.
- Conduct cabin leak test.
- Conduct Design Engineering Inspection (DEI).
- Install thermal and micrometeoroid shielding.
- Weigh and determine center of gravity.

DESCENT STAGE

- Rotate and clean structure.
- Install required subsystems (propulsion, ECS) associated plumbing and electrical harnesses. Leak check plumbing and perform DITMCO checkout.
- Cold flow ECS and propulsion systems.
- Rotate and clean vehicle.
- Install G&N antenna, associated "black boxes" and experiment packages.
- Mate with ascent stage and vibrate Demate following vibration.
- Conduct Design Engineering Inspection (DEI).
- Install thermal and micrometeoroid shielding.

JOINED ASCENT AND DESCENT STAGES

- Weigh and determine center of gravity.
- Align required systems and/or experiments.
- Conduct Formal Engineering Acceptance Tests (FEAT).
- Pack and ship to launch site.

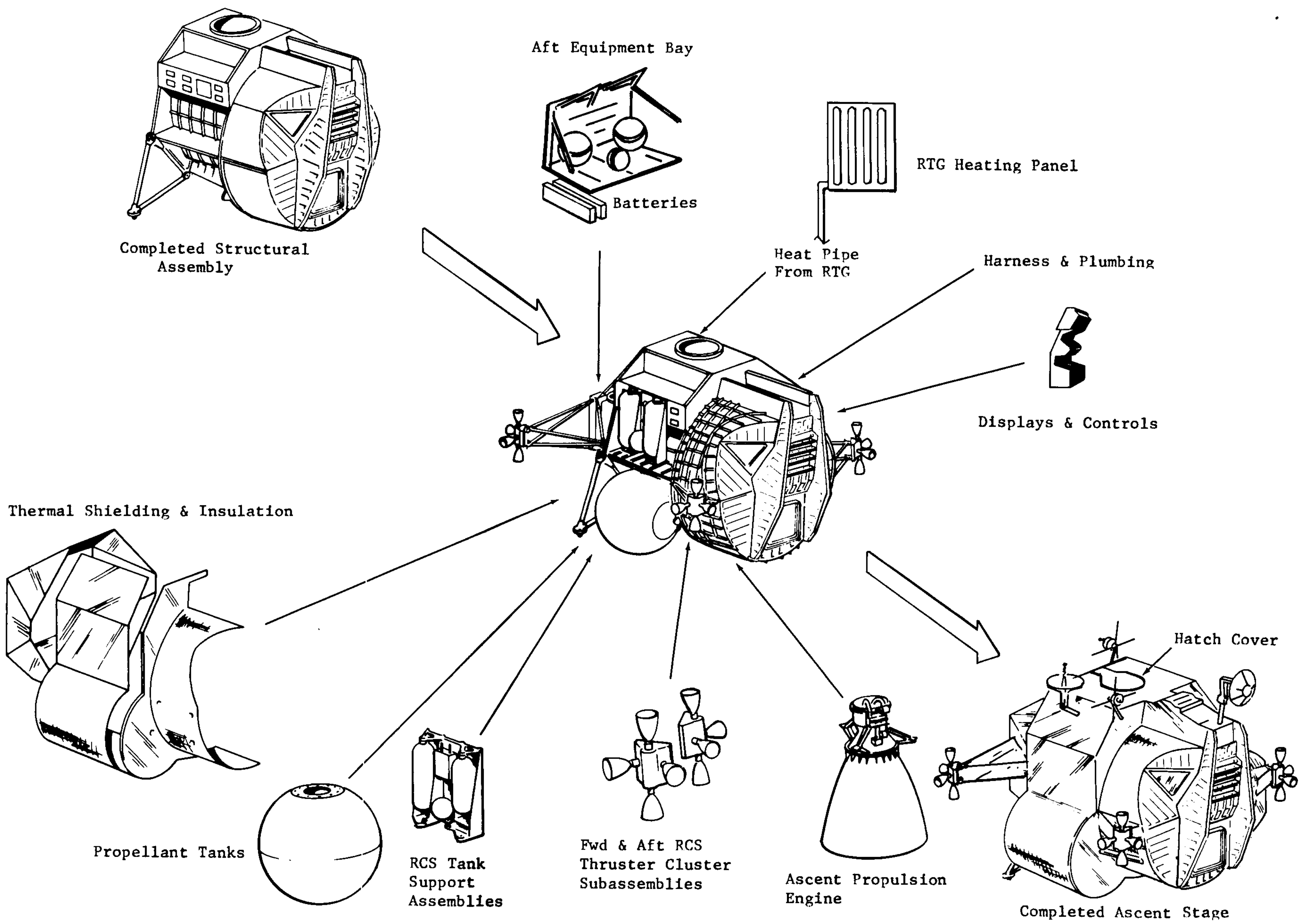


Fig. 6-1 Final Assembly Flow - LEM Taxi Ascent Stage (Config. 5)

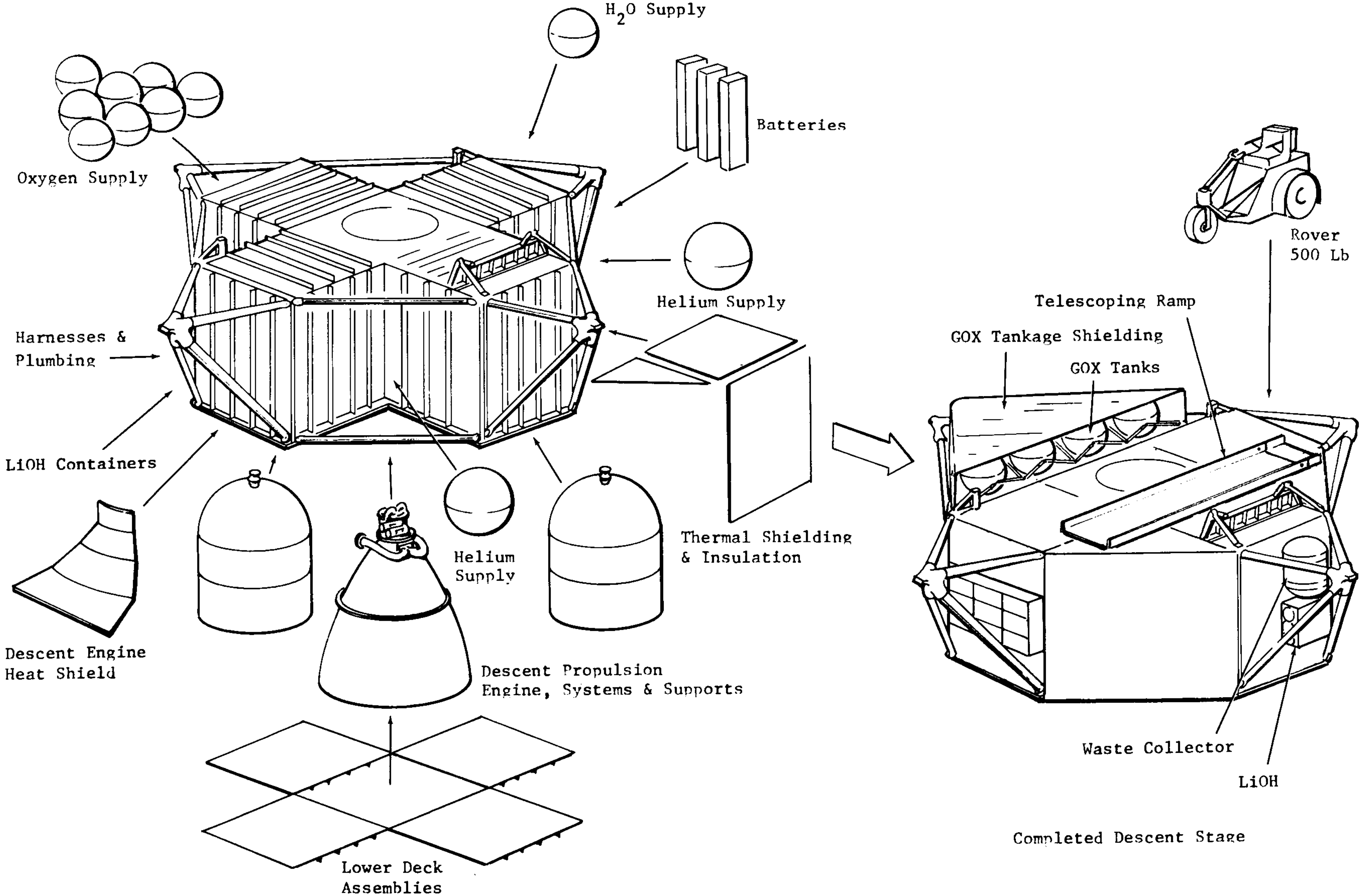


Fig. 6-2 Final Assembly Flow - LEM Taxi Descent Stage (Config. 5)

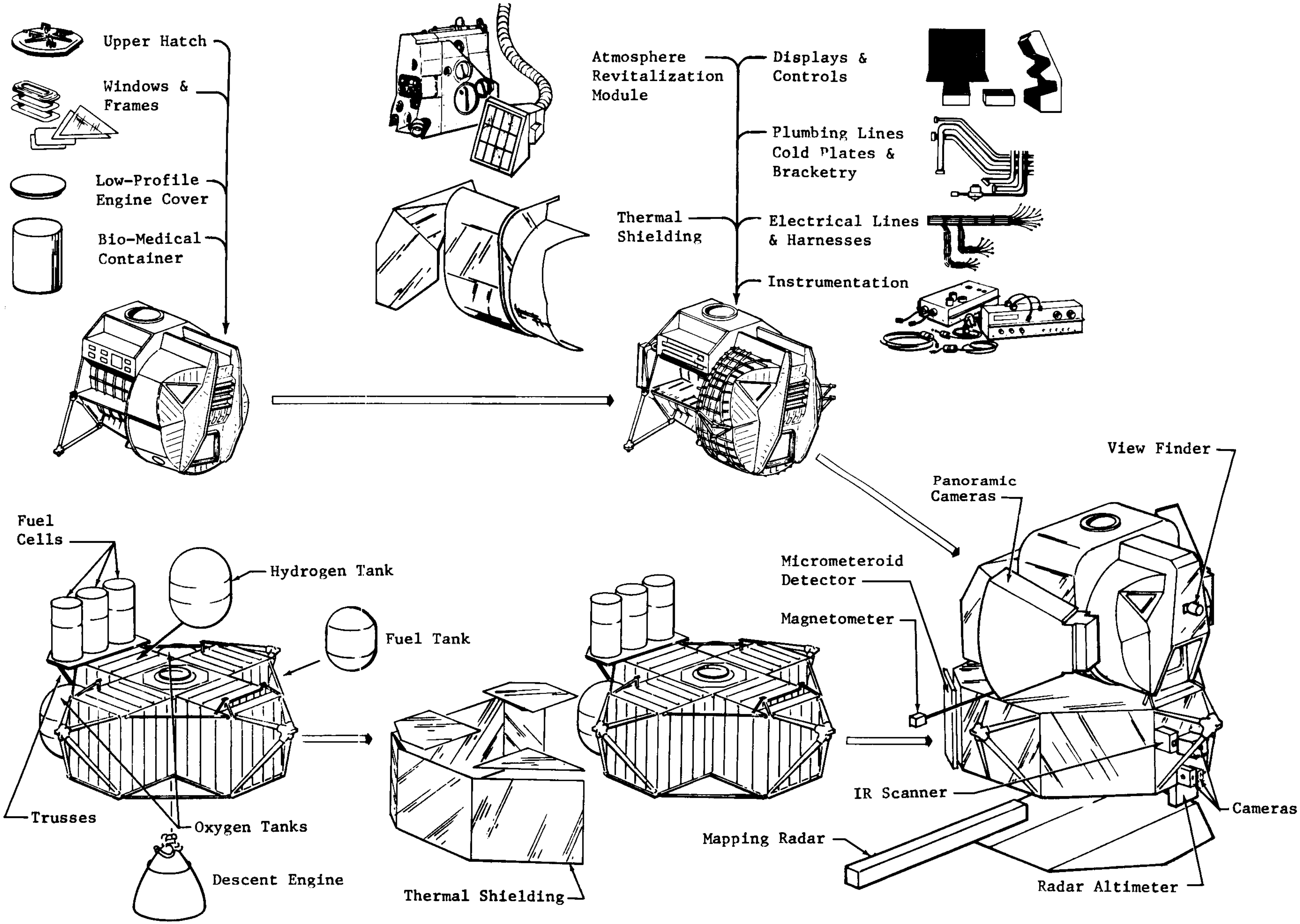


Fig. 6-3 Final Assembly Flow - LEM Lab

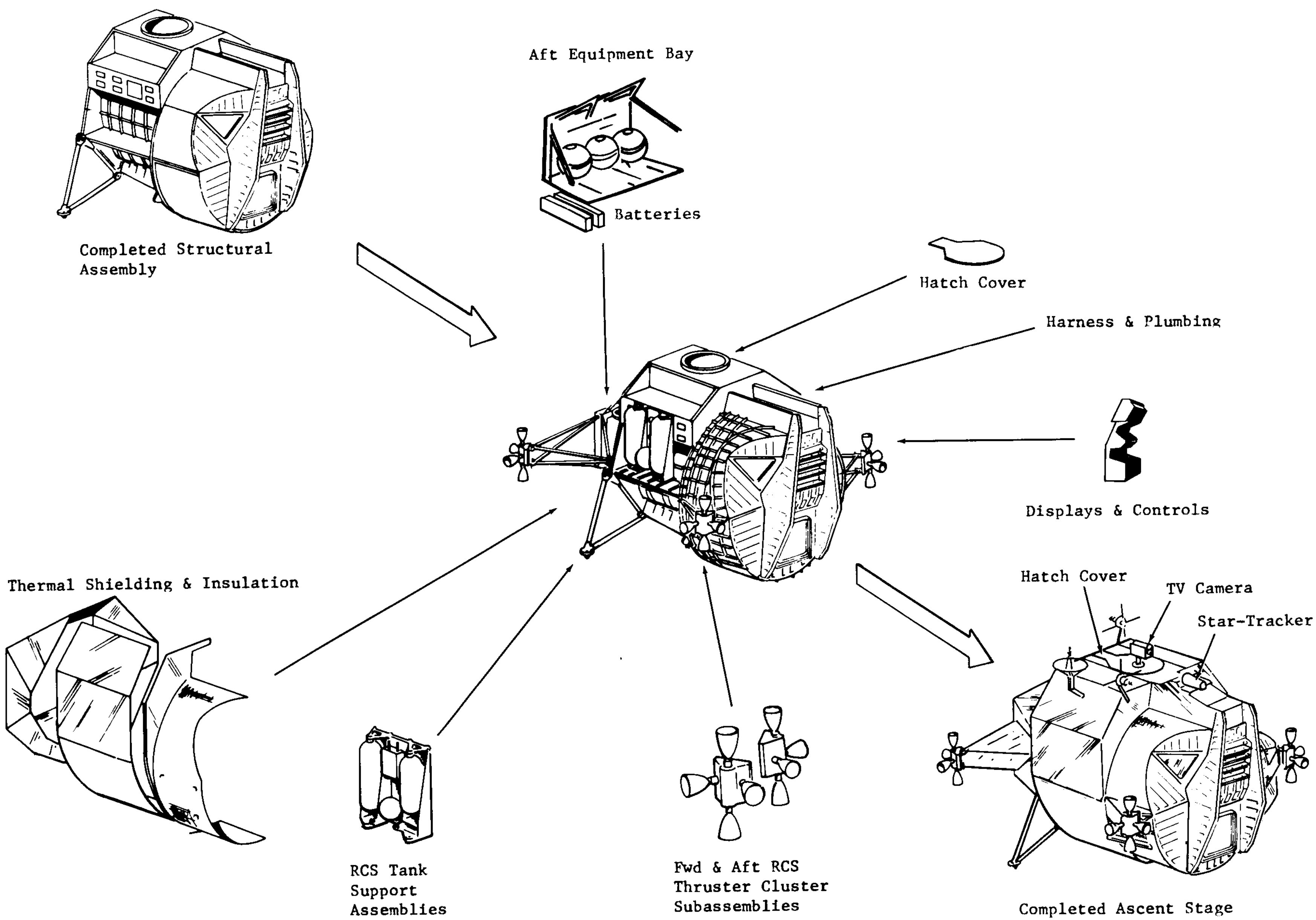


Fig. 6-4 Final Assembly Flow - LEM Shelter "1" Ascent Stage

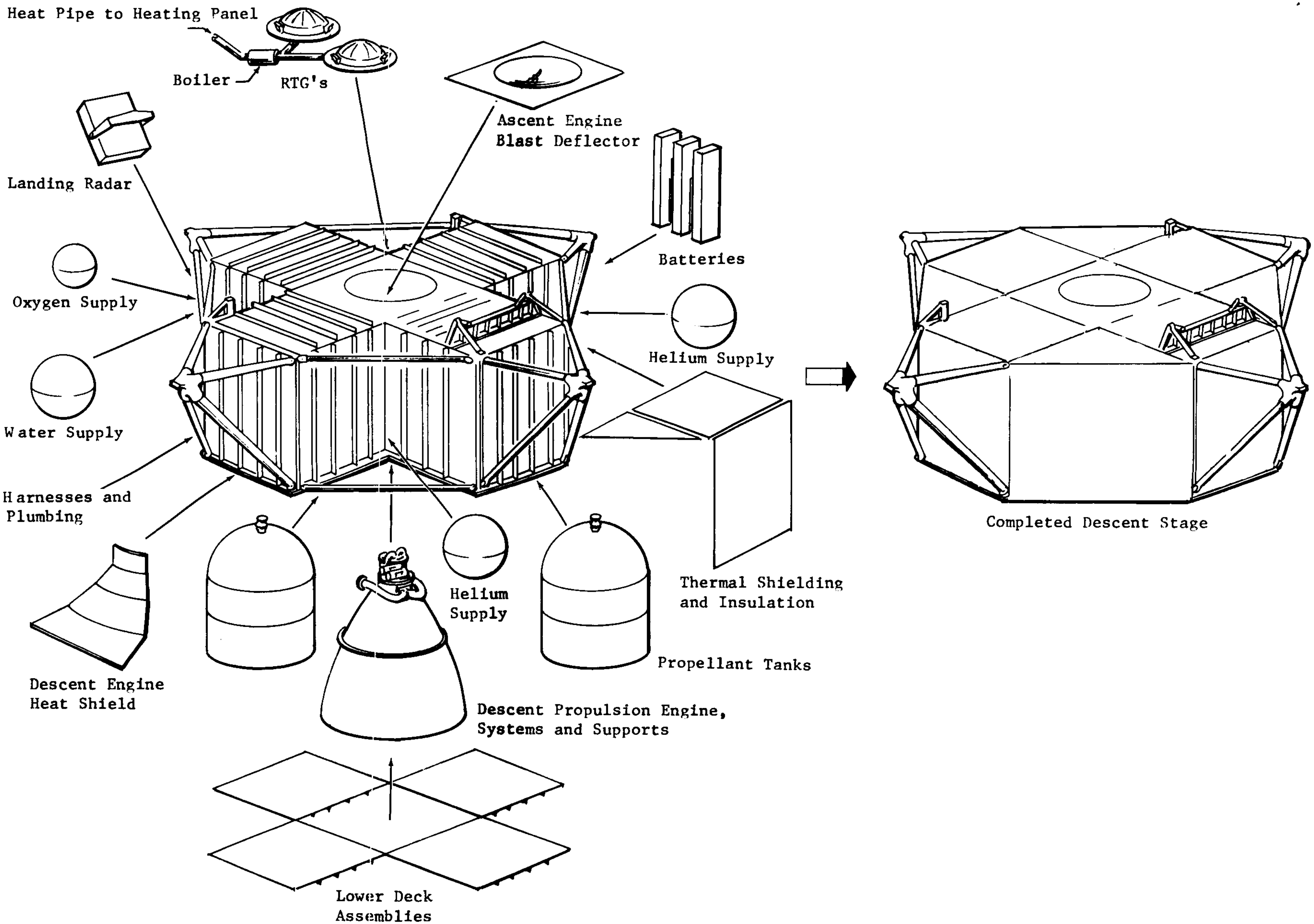


Fig. 6-5 Final Assembly Flow - LEM Shelter "1" Descent Stage

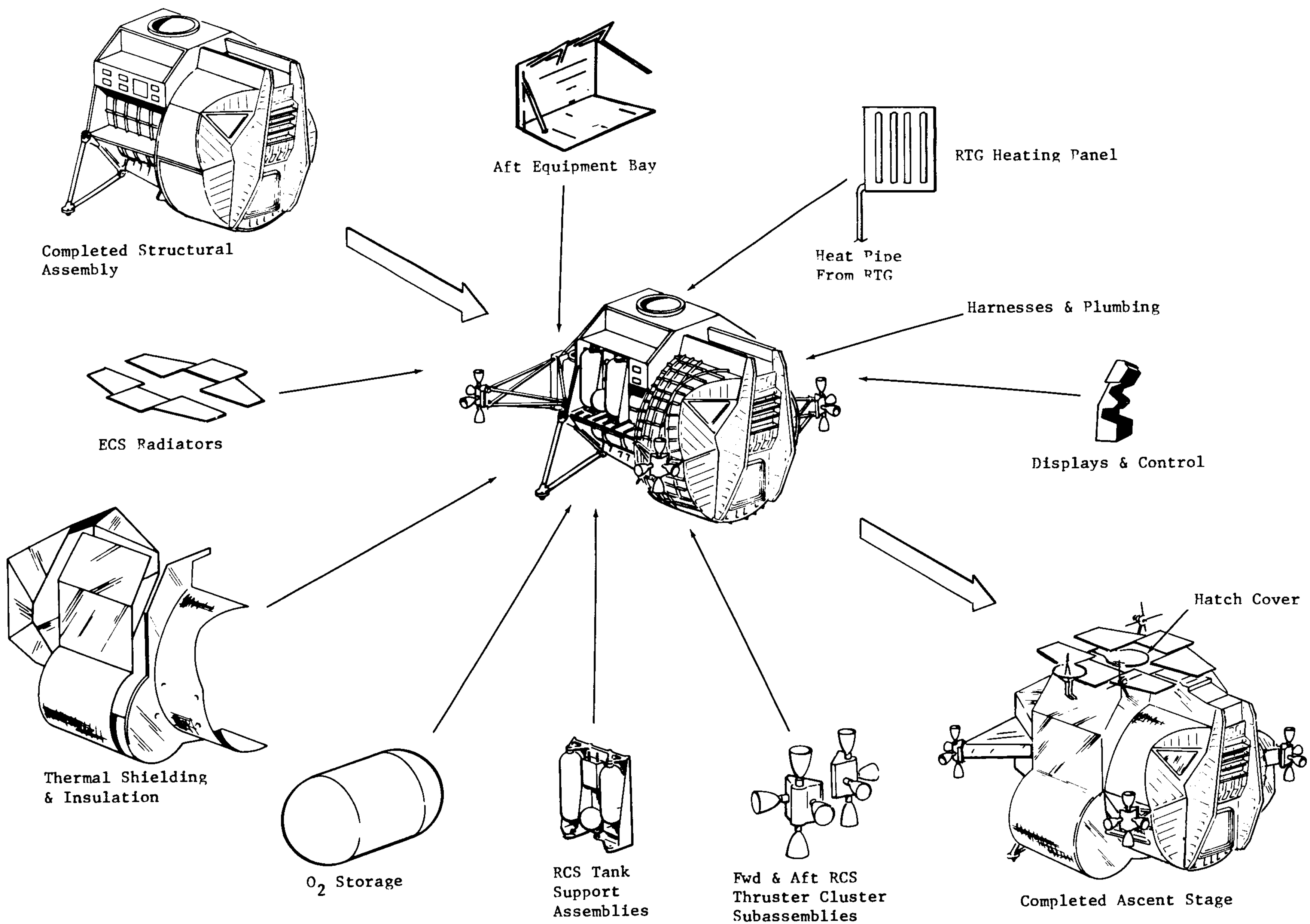


Fig. 6-6 Final Assembly Flow - LEM Shelter "2" Ascent Stage

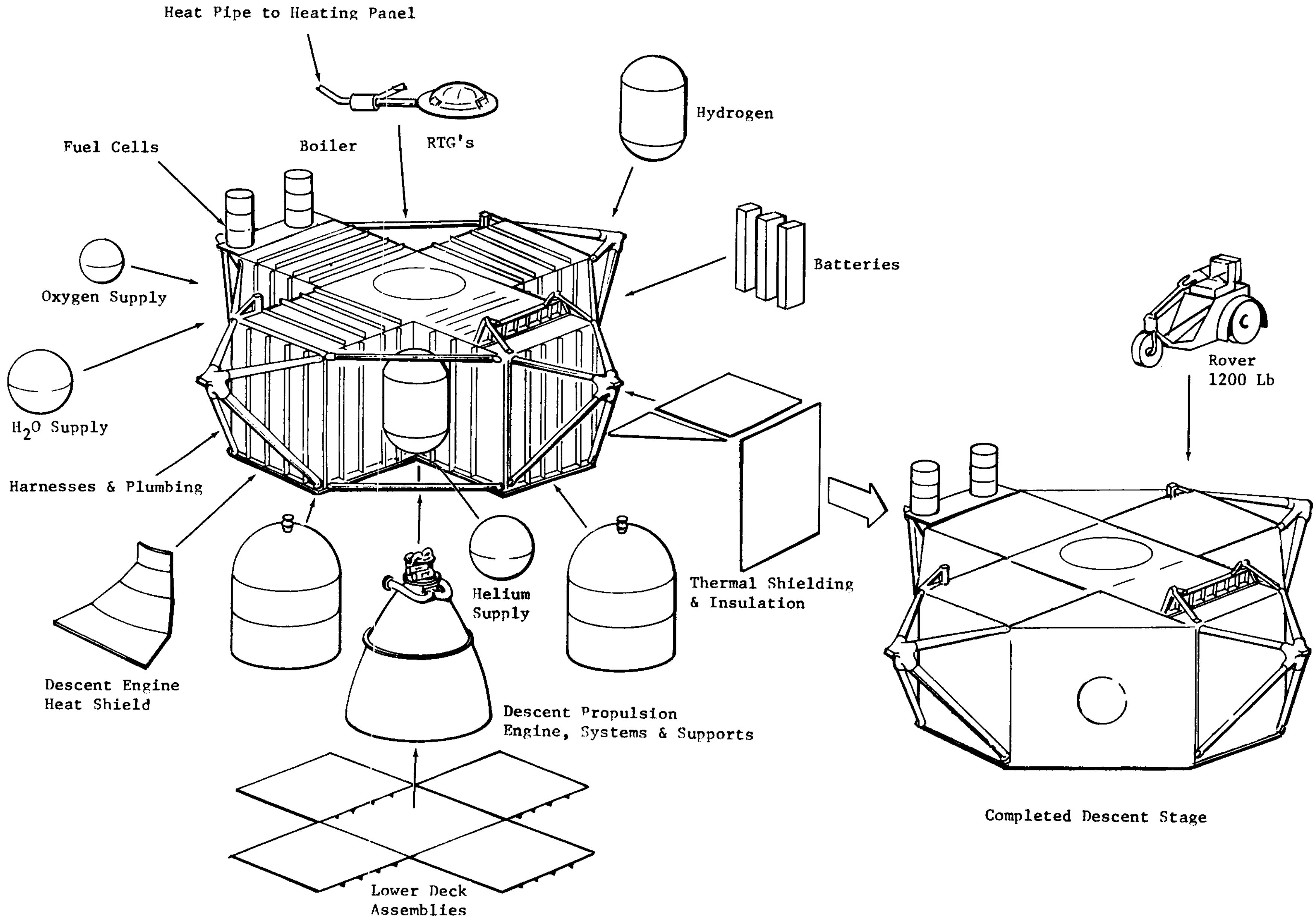


Fig. 6-7 Final Assembly Flow - LEM Shelter "2" Descent Stage

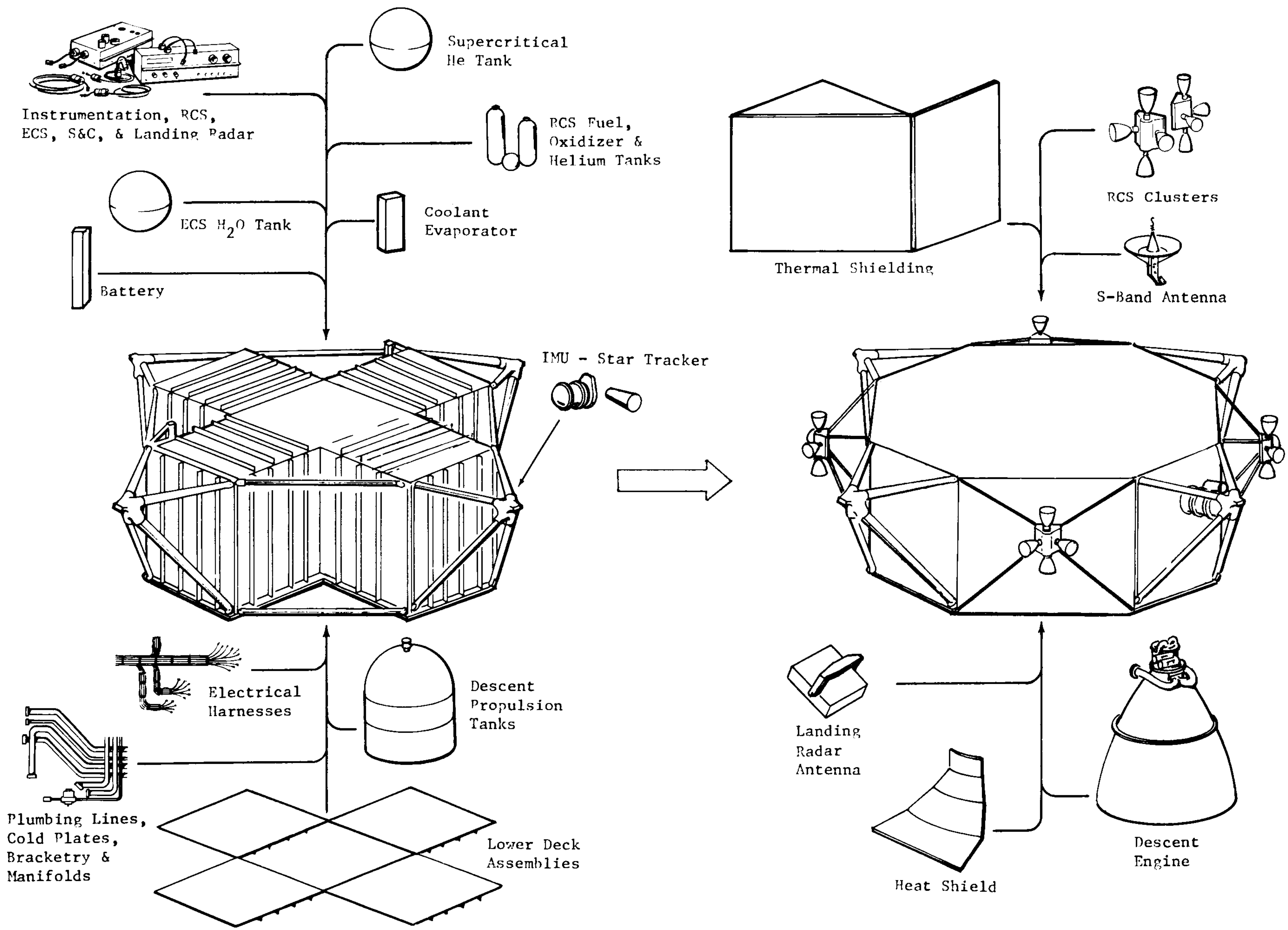


Fig. 6-8 Final Assembly Flow - LEM Truck

6.6 SCHEDULES

Preliminary schedules for AES configurations have been developed based on available LEM planning. The structural assembly schedule for the ascent and descent stages will be essentially the same as the LEM schedule since the basic AES structural arrangement is unchanged. The final assembly/checkout sequence for the Shelter and Taxi are equivalent to the LEM since the modifications are not pacing items. As shown in Fig. 6-9 the time in station is based on the checkout procedures involved such as, rotate/clean and cold flow, rather than system complexity. Subsystem and equipment installation for the Shelter and Taxi are considered trade-offs for this preliminary plan since detailed information on subsystem modification is not available at this time. The LEM Lab configurations (Fig. 6.-10) are expected to require 5-6 weeks less than the basic LEM since reduced subsystem requirements (engines, propulsion, etc.) are not balanced by the additional time required for experiment integration. The Truck assembly sequence Fig. 6-11) indicates a considerable decrease over a basic LEM due to the elimination of the ascent stage but, the LEM Truck requires 12-1/2 weeks more than a LEM descent stage because of the additional subsystem installations and associated checkout procedures.

6.7 MANUFACTURING FACILITIES

The AES program can be accomplished without major tooling, equipment, facility or floor space additions over those planned or available for the LEM program. Assuming a non-interference schedule, the AES program does not require more than eight vehicles in process at one time and this is within the planned LEM manufacturing capability. Subsystem changes and experiment integration requirements will require additional tooling, checkout equipment and ground support equipment but these are expected to be minor compared to planned in-house manufacturing facilities.

1	2	3	4	5	6	7	8	9	10	11	12	13	14

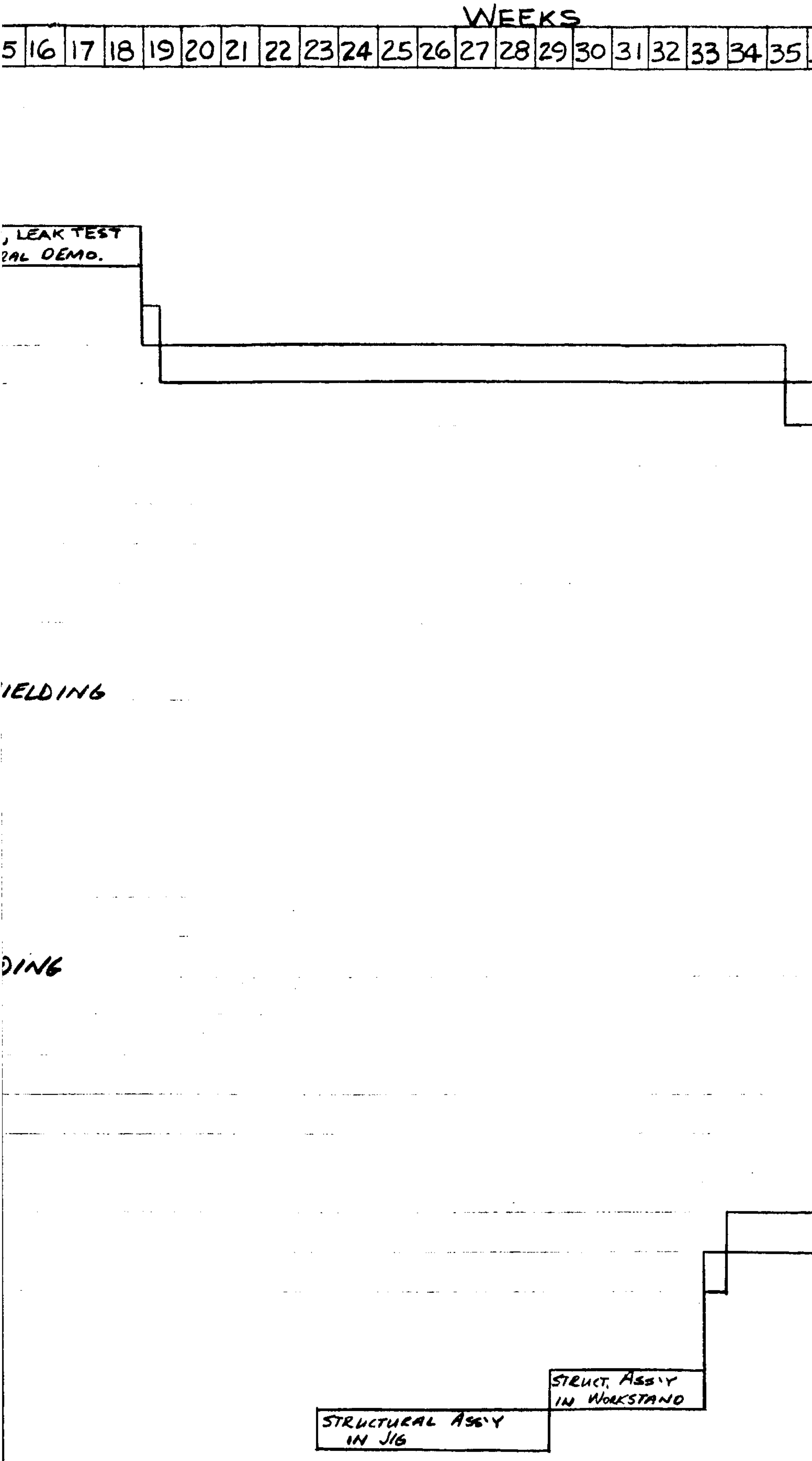
STRUCTURAL ASSEMBLY
- ASCENT

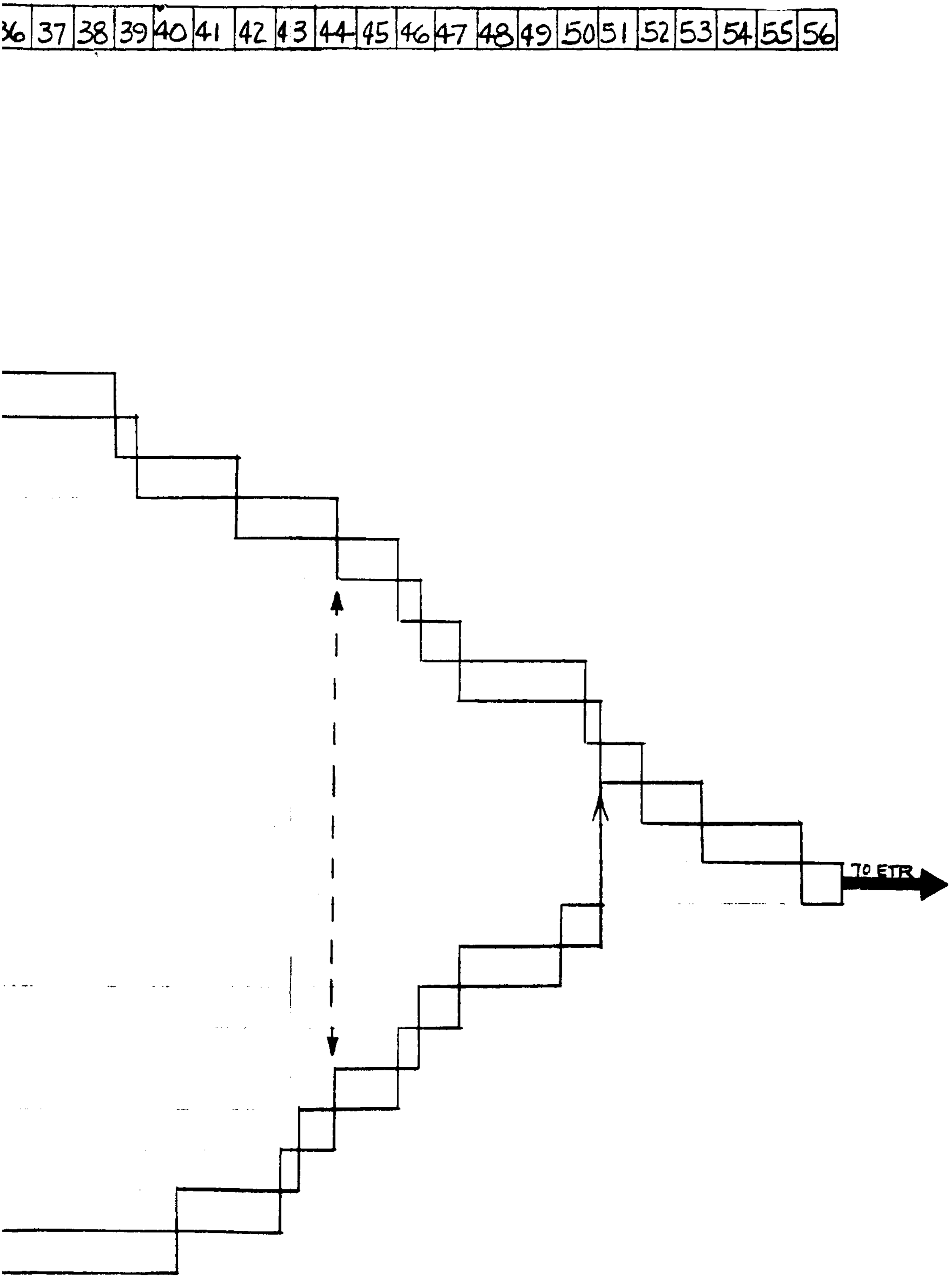
FACE ASS'Y
MACHINE TRIM
ASCENT STAGE STRUCTURAL ASS'Y
MID SECTION ASS'Y
CLEAN UP STRUCTU

FINAL ASSEMBLY & ACC. TESTS

- ASCENT
  - ROTATE & CLEAN
  - SUBSYSTEM INSTALLATION
  - COLD FLOW
  - ROTATE & CLEAN
  - ERA INSTALLATION
  - VERIFICATION
  - MATED VIBRATION
  - CABIN LEAK
  - DEI
  - INSTALL INSULATION & THERMAL SH
  - WEIGH & C.G.
- JOINED STAGES
  - MATE, WEIGH & C.G.
  - ALIGNMENT
  - FEAT
  - PACK & SHIP
- DESCENT
  - INSTALL LANDING GEAR
  - INSTALL INSULATION & THERMAL SHIEL
  - DEI
  - INSTALL ENGINE
  - MATED VIBRATION
  - EXPERIMENT & ERA INSTALLATION
  - ROTATE & CLEAN
  - COLD FLOW
  - SUBSYSTEM INSTALLATION
  - ROTATE & CLEAN

STRUCTURAL ASSEMBLY
- DESCENT


WEEKS
5 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
, LEAK TEST
RAL DEMO.
IELDING
DING
STRUCT. ASS'Y IN WORKSTAND
STRUCTURAL ASS'Y IN JIG



(LEM · 11 REFERENCE)

Fig. 6-9 Fabrication & Assembly Schedule - Shelter and Taxi

1	2	3	4	5	6	7	8	9	10	11	12	13	14

STRUCTURAL ASSEMBLY

- ASCENT

FACE ASS'Y

MACHINE TRIM

ASCENT STAGE STRUCTURAL ASS'Y

MID SECTION ASS'Y

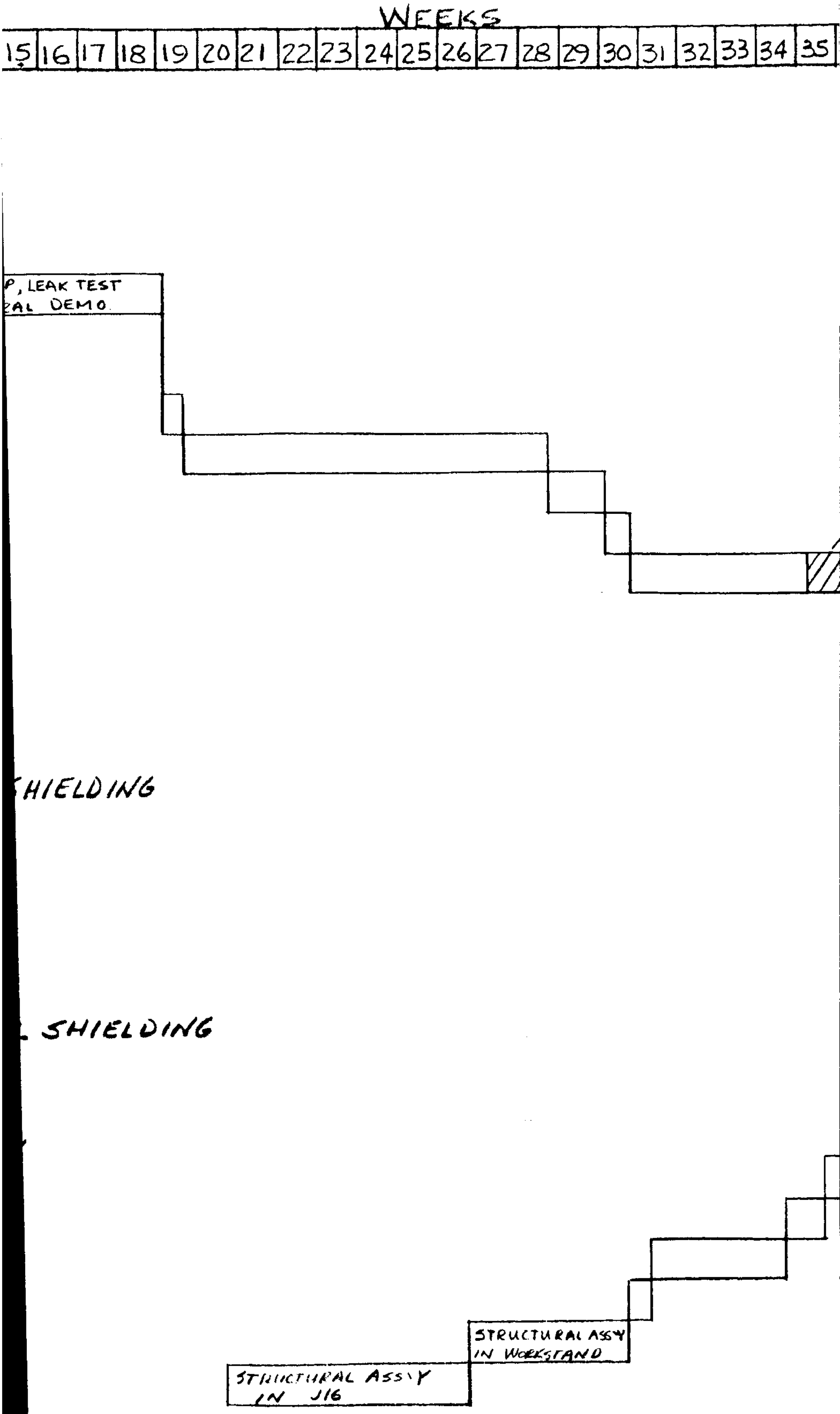
CLEAN-U STRUCTU

FINAL ASSEMBLY & ACC. TESTS

- ASCENT
  - ROTATE & CLEAN
  - SUBSYSTEM INSTALLATION
  - COLD FLOW
  - ROTATE CLEAN
  - EXPERIMENT & ERA INSTALLATION
  - VERIFICATION
  - MATED VIBRATION
  - CABIN LEAK
  - DEI
  - INSTALL INSULATION & THERMAL S
  - WEIGH & C.G.
- JOINED STAGES
  - MATE, WEIGH & C.G.
  - ALIGNMENT
  - FEAT
  - PACK & SHIP
- DESCENT
  - INSTALL INSULATION & THERMA
  - DEI
  - MATED VIBRATION
  - EXPERIMENT & ERA INSTALLATION
  - ROTATE & CLEAN
  - COLD FLOW
  - SUBSYSTEM INSTALLATION
  - ROTATE & CLEAN

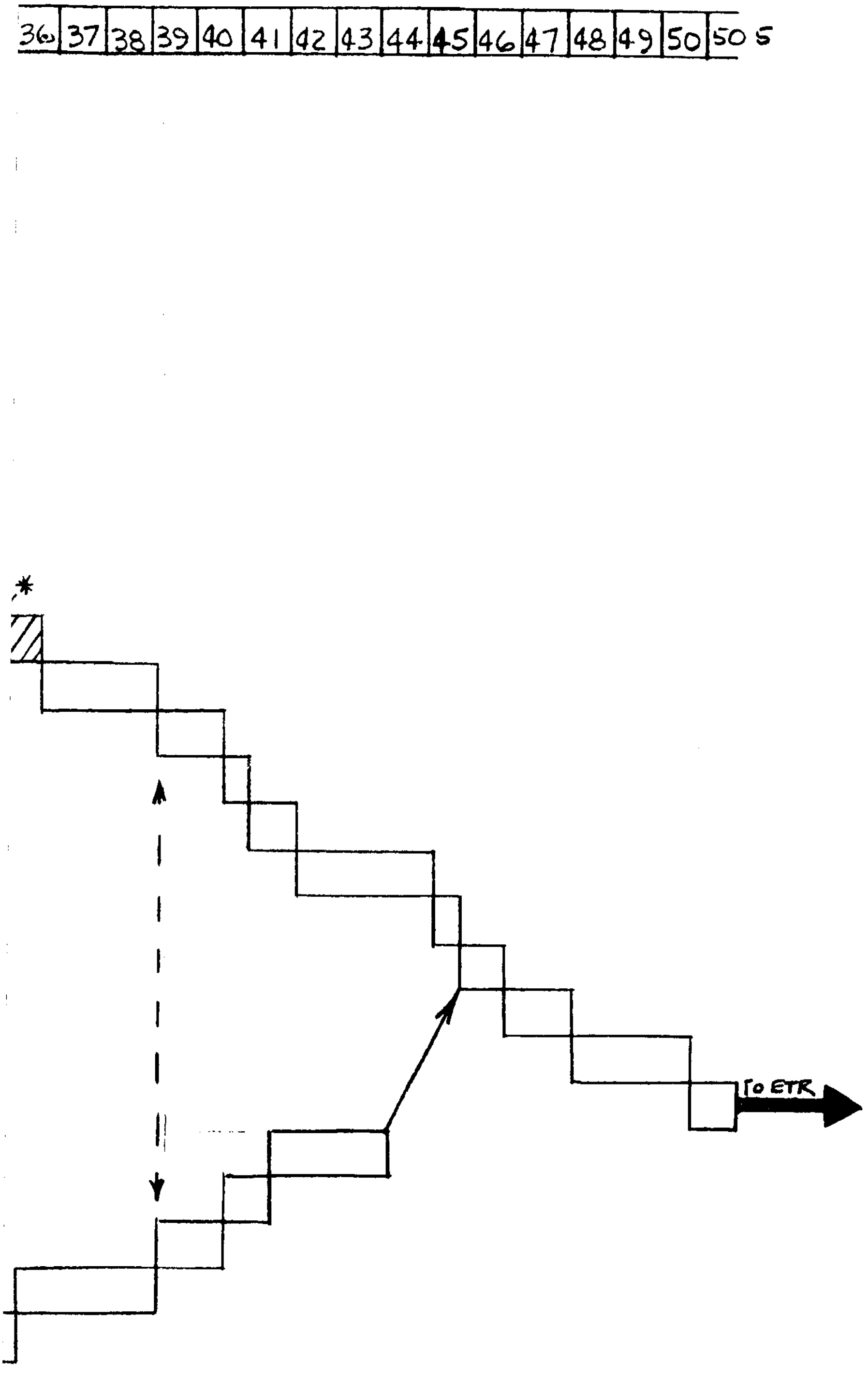
STRUCTURAL ASSEMBLY

- DESCENT



* SHADED AREA RE
DUE TO DELETION

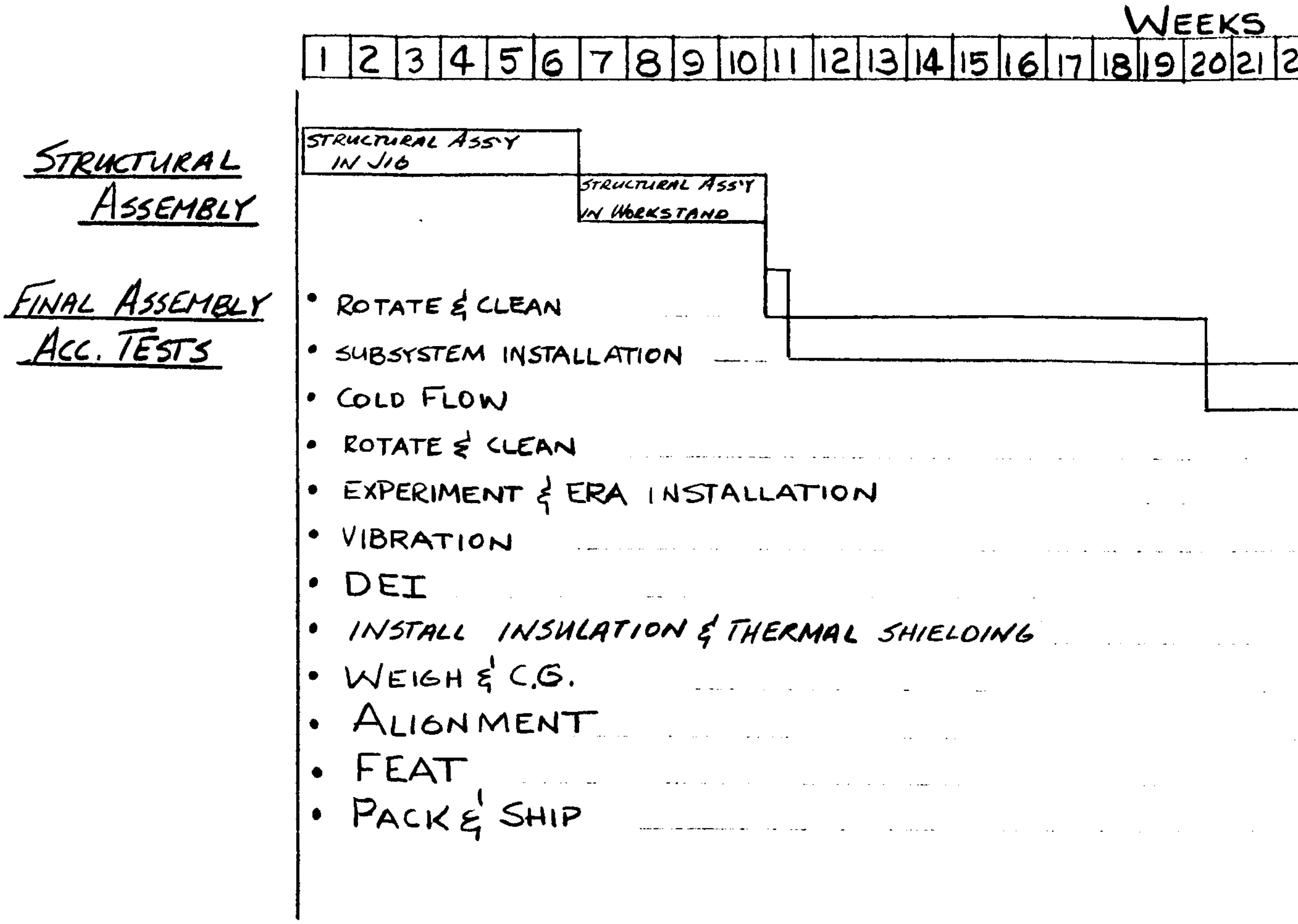
2



3

PRESENTS DECREASE FOR CONFIGURATION 2
OF PANORAMIC CAMERAS IN ASCENT STAGE

Fig. 6-10 Fabrication & Assembly Schedule -
LEM Lab Configurations 1 & 2



WEEKS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
STRUCTURAL ASSEMBLY
STRUCTURAL ASS'Y IN JIG
STRUCTURAL ASS'Y IN WORKSTAND
FINAL ASSEMBLY ACC. TESTS
• ROTATE & CLEAN
• SUBSYSTEM INSTALLATION
• COLD FLOW
• ROTATE & CLEAN
• EXPERIMENT & ERA INSTALLATION
• VIBRATION
• DEI
• INSTALL INSULATION & THERMAL SHIELDING
• WEIGH & C.G.
• ALIGNMENT
• FEAT
• PACK & SHIP

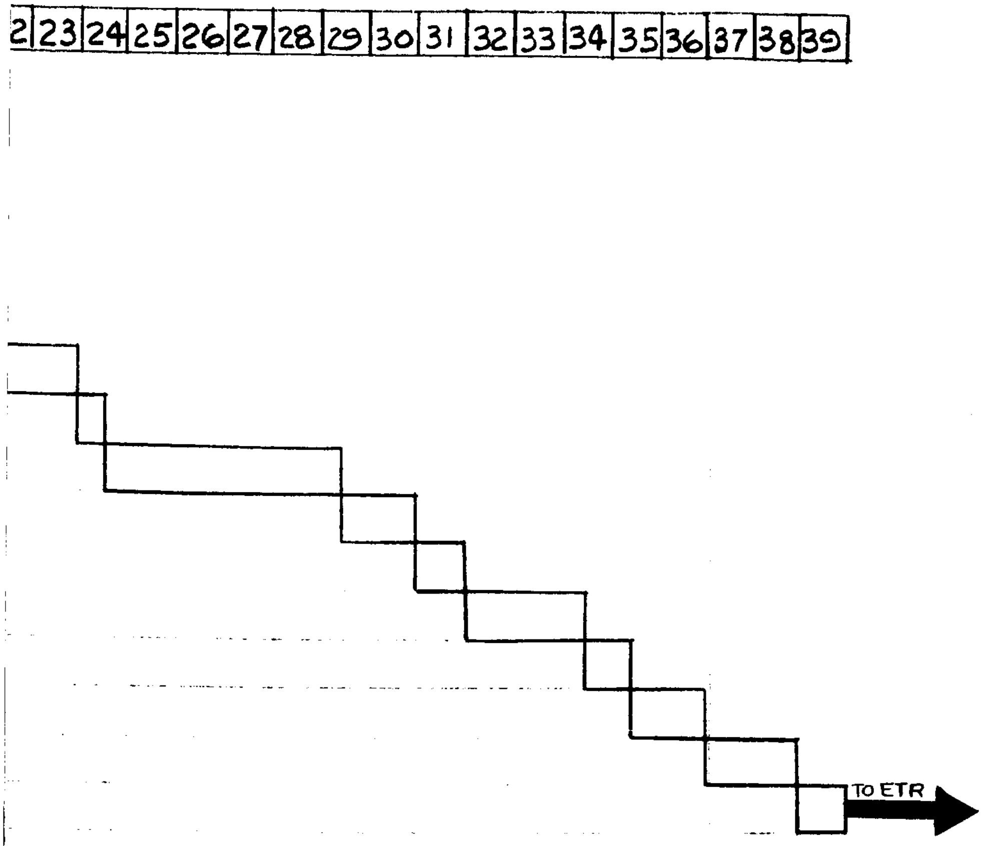


Fig. 6-11 Fabrication & Assembly Schedule - LEM Truck